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THE INFLUENCE OF MICRO CRACKS APPEARING DURING CONCRETING OF ROAD VIADUCTS AND THEIR IMPACT ON A FROST-THAW RESISTANCE

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Abstract. In the latest period hundreds of concrete viaducts were built in Poland within a short time range. The cases of destruction of concrete road viaducts described by the author in the article concern in the construction of such structures in various parts of our country, such as central regions of Poland, Warmia-Masuria, south – east - a total of about 30 objects. The occurring phenomenon is related to the micro cracks of the cement matrix which are not visible on the surface of the elements and become visible only after the cyclic freezing process as a result of the standard F150 frost resistance test, the so-called the standard method according to Annex N to the PN-B-06265: 2018 standard. The destruction took an unprecedented course and aroused much discussion in the scientific community. This article summarizes this discussion and indicates the root cause of the destruction.

Keywords: Concrete Viaducts, Frost Resistance of Concrete, Micro Cracks, SEM and EDS Analyses

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1. INTRODUCTION

After 2010, hundreds of concrete viaducts were built in Poland within a short time range. Their characteristic feature was the use of C40/50 class of concrete containing CEM I 42,5 or CEM I 52,5 HSR cement. Construction often took place during wintertime. Unfortunately, despite successful laboratory tests, the concrete prepared on the construction site often did not achieve the assumed freeze resistance (F150). The lack of freeze resistance in concrete has an unusual course. Higher than normative decrease of strength occurs with simultaneous high tightness coming about. In addition, there is no surface spalling, typical for the low freeze resistance concrete, no edge curvature, etc. On the sample surface, however, a characteristic mesh of white leakage of unknown chemical compounds appears around big aggregate grains[1]. The world literature has presented many cases of micro cracks appearing in cement matrixes. This is the consequence of delayed ettringite formation (DEF) [2-9], a 'weak' form of sulphate attack, or the creation of secondary ettringite formation (SEF) [10,11]. DEF embraces thermal cracking that has been around for a long time. In SEF, increased deformation occurs that is connected with the destruction of the structure, while the micro-region of cracks show the presence of an alkali silica gel and a crystalline secondary ettringite. DEF reactions have also been noted in cracks found in road viaducts in France (described in detail by Loïc Divet and Alexandre Pavoine in [12]), but the example analyzed in this paper is different. In the example described by the author, instead of ettringite formation, no expansive phosphate and carbonate salts were evident. Moreover, according to EDS-SEM analysis, the cement matrix was characterized by micro cracks filled with white salts [13,14,15].

In the viaduct tested in 2016, it turned out that micro cracks were already noticed in the process of concreting the structure and were thought due to both the high hydration strength of cement CEM I 52.5 and a large temperature gradient. In testing, it was noticed that as the number of freezing cycles increases, the velocity of an ultrasound wave passing through the concrete samples decreases, which is the result of the micro-scratches. Using the scanning microscope and SEM analysis, an increase of micro distance during freezing processes was also measured and found to result in a large reduction in compressive strength - even to 50%. Decisions regarding further safe operation of these viaducts are required.

2.CIRCUMSTANCES OF OCCURRENCE OF CRACKS OR MICRO CRACKS IN THE COMPLETED ROAD VIADUCTS

The basic example of the previously described cracks of concrete structures of road bridges and viaducts that make their appearance in longer intervals of time are indicated in the cases described in 2002, by Loïc Divet and Alexandre Pavoine in the work [12]. The five studied bridges were constructed between 1955 and 1990. Geographically, they are located south of a line extending from Nantes to Besançon. Herein, the damage never affects the entire structure, and is mainly apparent in the relatively massive elements.

In the report, the initial technical condition of a particular bridge which was constructed during 1980-1981 was very well documented. It was re-tested in 1989 and 1997, and further crack propagation was found (see Fig. 7 and 9 in [12]). Herein, the cross head on the North pier has closely-spaced vertical cracking on both sides, with a maximum crack aperture varying between 0.2 mm and 1.2 mm. In contrast, while the cross head of the South pier suffers from the same type of distress, the structure seems less severely affected. The maximum crack aperture is only 0.3 mm, except on the east end where widths attain 1.7 mm. Furthermore, the network of cracks is denser and efflorescence can be observed in this zone. Lastly, the detailed inspection conducted in 1997 showed a lack of drainage from the supports (abutments and piers). In their conclusions, Loïc Divet and Alexandre Pavoine said that the fundamental mechanisms involved in this pathology have not yet been fully elucidated, but a number of factors clearly seem to be essential [12]:

- the high degree of heating (about 80°C) that occurs in the concrete is the result of several processes. Less exothermic cement should have been used in mass concrete of this type. Also, the concretes were cast in the summer and have a high cement content (approximately 400 kg/m^3 of CEM I 55R or CEM II A 55);

- the alkali content of the cements used was relatively high (above 0.6 % Na2O equivalent). However, the SO_3 and C3A contents were not very high (approximately 2.6% of SO3 and between 7% and 11% of C_3A);

- the type of aggregate also seems to be critical. It is likely that siliceous aggregate (in particular of the quartz type) encourages the formation of potentially expansive ettringite at the paste/aggregate interface,

- wetting/drying cycles or relatively humid conditions are also instrumental.

In the road viaducts analysed by the author of this article, certain circumstances were similar to those described by Divet and Pavoine, but the main difference is that the micro cracks appeared just after concreting, they were invisible to the naked eye, and they were revealed only after about 100 freezing-thawing cycles.

The laboratory test results of fresh concrete mix, as well as the examination of hardened concrete samples confirmed the correct selection and proportions of components, as well as the values of all concrete parameters specified in the design specification expected at the design stage. During the construction of the road flyovers, however, numerous deviations from the laboratory conditions were noted, which resulted in undercutting the concrete mix and concrete, and, as a consequence, led to the loss of the frost-thaw resistance of the structural concretes. The parameters of the concrete mixtures used in the completed bridge structures are summarized in Table 1.

Table 1. Recipe and basic technical data for C40 / 50 concrete bridge class, F150

Laboratory recipe			**Physical-mechanical parameters of the mixture and concrete**
Cement 52,5 N-HSR/Na	-	400 kg	f_{cm7} = 47,5 MPa
Water	-	157 l	f_{cm28} = 73,4 MPa
Sand	-	670 kg/m^3	Aeration 5,20 %,
Aggregate 2/8	-	438 kg/m^3	Fall cone 12 cm, after 1 hour - 16 cm
Aggregate8/16	-	679 kg/m^3	Density 2349 kg/m^3
Plasticizer	-	0,50 % mc	Water absorption 4,1 %
Superplasticizer	-	0,80% mc	Permeability W8, water penetration 1,8 cm
Aeration admixture 0,08% mc	-		Frost resistance F150 for drop in strength ΔR = 5,2 % and mass ΔG = 0,8 %

The basic deviations are:

- execution of structures at temperatures down to – 10°C,
- change in consistency: instead of a fall of 12/16 cm, the fall of a cone of 18 cm and even of 25 cm were recorded, with such a discrepancy in the results, the supplied concrete mix was considered to be qualitatively unstable, and at the initial stage of the assessment it was considered one of the reasons for the lowering of the concrete compressive strength,
- the degree of aeration of the concrete mix on the construction site ranged from 3.5% to 4.9% and was lower than the test aeration of 5.2%, but indicator A300 was greater than 1,5%,
- 3.7% to 9.1% lower 28 days compressive strength of concrete was evident and was due to concreting during periods of low temperatures,
- lower by 9.7% weight absorption of samples from the construction was found, along with higher tightness of concrete,
- significantly lower strength of concrete subjected to cyclical freezing and thawing up to was indicated. This was to the extent of approx. 30% to 54% - criterion F150 is not met,
- mass increase of samples subjected to freezing / thawing was noted by 0.95% to 1.63%,

- no concrete exfoliation from the surface of the samples was indicated, clear cracks of the samples in the entire volume were filled with a white salt sediment (Fig. 1).

a)  b) 

Fig. 1 Grid micro cracks filled with white salt sediment on both samples 15x15x15 cm taken during the concreting of the viaducts (a), as well as cylindrical samples Ø100 mm cut from the flyover structure (b)

In the examination of this concrete, the cyclic freezing process was found to lower the strength, but did not cause the sample to be destroyed, while the weight loss as in the case of non-aerated cones, did not meet the criteria of concrete freeze resistance. Due to the non-standard appearance of samples after freezing tests, additional non-destructive ultrasonic tests of core samples taken from the flyover plates were performed to compare the structure of the concrete before and after 150 freezing cycles. On analysing the dependencies contained in Fig. 2, the velocity of the impulse flow through un-frozen samples was noted to be in the range of 5700-6200 m/s (concrete strength 50-75 MPa, respectively), which confirms the high technical parameters of the concrete, its compactness and low absorbability.

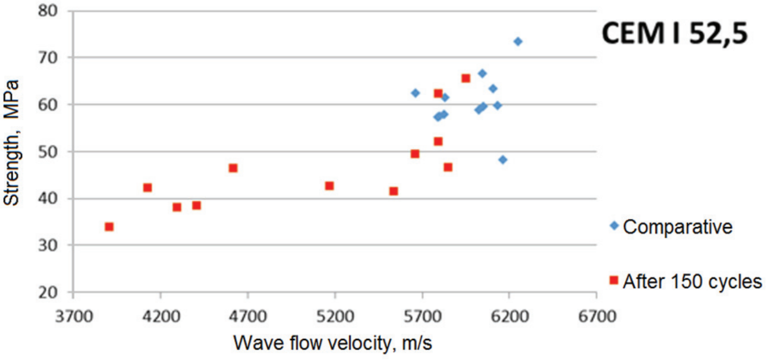


Fig. 2 Relation of the ultrasonic wave flow velocity - concrete compressive strength of Ø100 mm well samples taken from road viaducts (details in [16])

In contrast, the frozen samples were characterized by very large spreads of both the pulse flow velocity from 3800 to 6100 m/s (strength 35 to 65 MPa, respectively), which confirms the damage to the internal structure of the concrete and indicates the reason for the low frost resistance of the concrete. Against the background of these studies, a thesis was formulated, that during concreting in winter, with the mass of road viaduct structures and the use of high-calorie cements, there is a high temperature gradient causing not only the clearly evident cracks, but also small micro cracks within the cement matrix . This thesis is confirmed by the data (Figures 3 and 4) of the main cement producer in Poland and the author's observations described in [15].

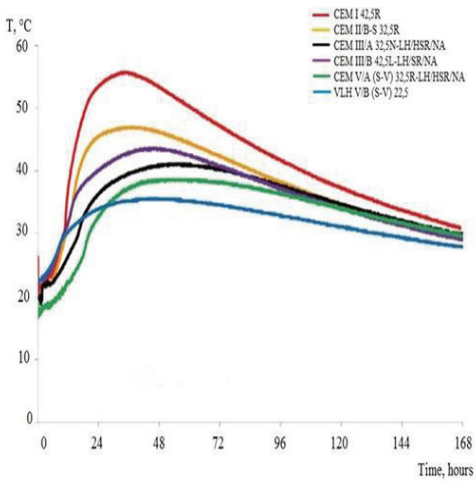


Fig. 3. Relative increase in concrete temperature when using different cements, starting from cements with high heat release kinetics to caves with the lowest calorific value

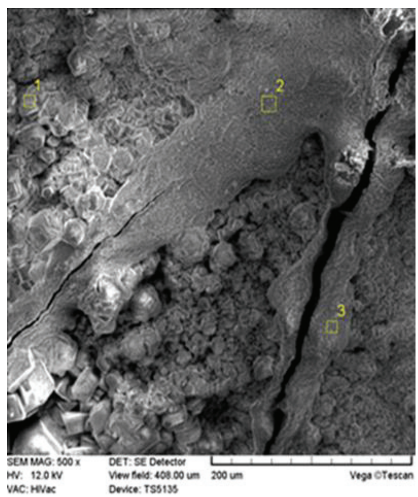


Fig. 4. Image of micro cracks in bridge concrete made with the cement 52,5 R

3. THE WIDTH OF MICRO CRACKS BEFORE AND AFTER THE CYCLIC FREEZING PROCESS. SEM, EDS AND XRD ANALYSIS

3.1. SCANNING TESTS

The samples were sputtered before testing for their frost resistance and after 150 freezing cycles. In the first stage of the tests, micro cracks in the concrete were induced, in the second, the nature of the micro cracks within the cement matrix and its filling was examined. The chemical composition of the white deposition after 150 freezing cycles was also determined. The results are shown in Fig. 5 to 8.

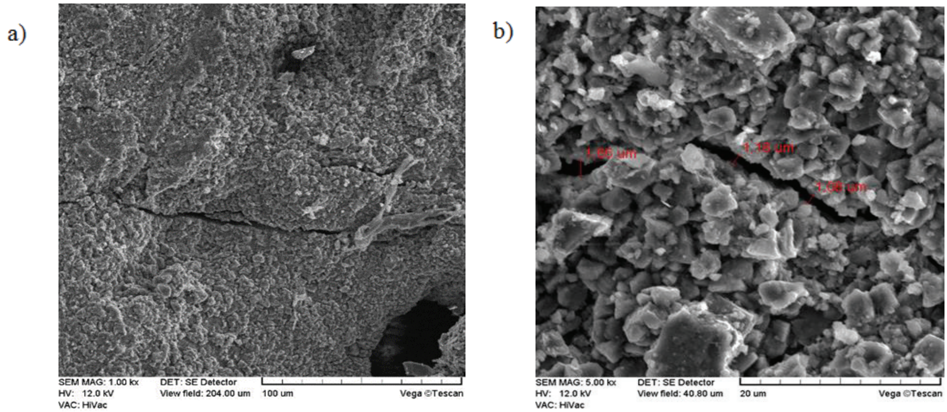


Fig. 5 Micro cracks of an unfrozen sample. Drawing (a): magnification 1000 x, observation field 200x200 µm. Drawing (b): magnification 5000 x, observation field 40x40 µm; width of the cracks from 1.08 to 1.65 µm

The conducted scanning tests showed that micro cracks were already formed in the unfrozen cement matrix. These, after 150 freezing cycles significantly expanded. In addition, over time, the micro cracks "overgrow" with calcium compounds and bent the structure. It was also observed that in the standard frost resistance test, when the samples are fully saturated with water, the micro cracks are filled with water and after about 80 freeze-thaw cycles the concrete sample is destroyed. The calcium compounds contained in the cement stone dissolve as well, which then accumulate in the micro-grids, causing their white color. Due to the looseness of the concrete structure, its strength decreases.

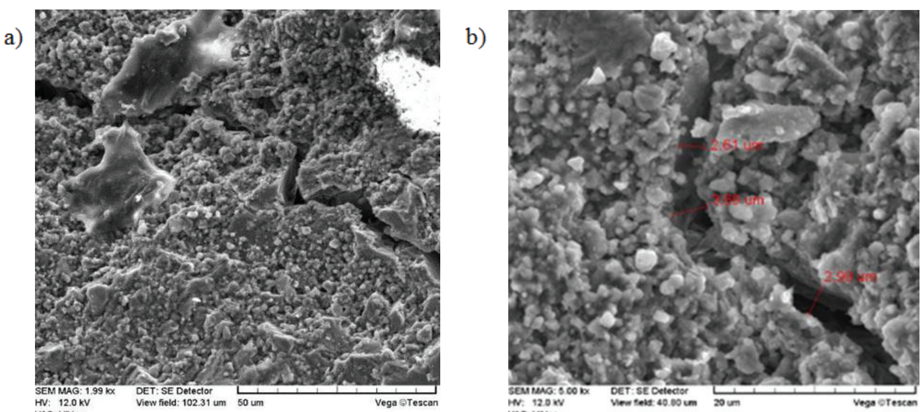


Fig. 6 Micro cracks of a frozen sample. Drawing (a): magnification 2000 x, observation field 100x100 µm. Drawing (b): magnification 5000 x, observation field 40x40 µm; width of the cracks between 2.61 and 3.69 µm

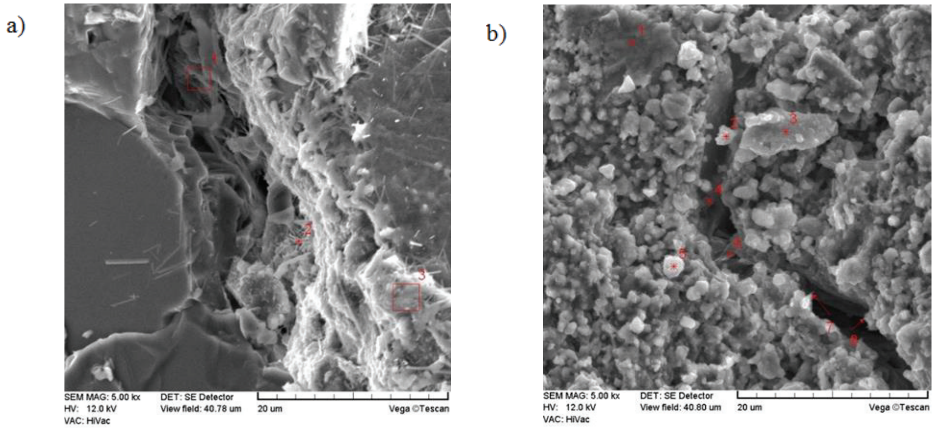
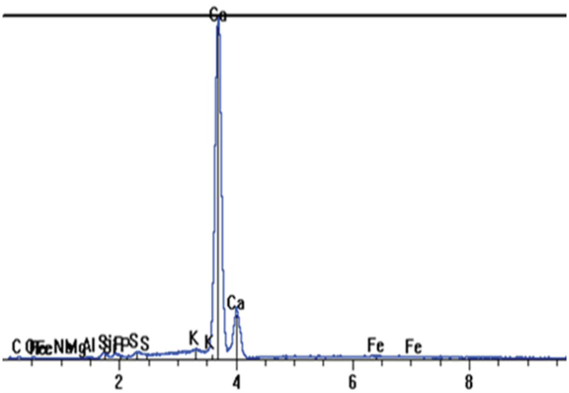


Fig. 7. Micro cracks (a) and theirs filling(b)



Element	Line	Wt%	At%
C	KA1	24,75	45,21
O	KA1	13,42	18,41
Na	KA1	0,00	0,00
Mg	KA1	0,18	0,17
Al	KA1	1,26	1,02
Si	KA1	9,00	7,03
P	KA1	0,18	0,12
Ca	KA1	48,89	26,76
Fe	KA1	1,06	0,42
S	KA1	1,25	0,86
K	KA1	0,00	0,00
Total		100,00	100,00

Fig. 8 Chemical composition of cracks from Fig. 7 – b. Note the very large amount of calcium and carbonates

As shown also in these studies, the white residue appearing in the micro cracks after the freezing process has a diverse chemical composition, from dissolved simple calcium compounds, to calcium carbonates, ferrates and sulfate derivatives.

Sulfate derivatives may also contain swelling salts that cause additional destruction of the concrete. For this reason, XRD analysis were performed to determine the chemical composition of the cement matrix.

3.2. XRD ANALYSIS

The advantage of this method is the ability to accurately determine the chemical structure of chemical compounds with almost absolute certainty, enabling the build of their real spatial model. No other analytical method gives such certainty, and such methods always leave the possibility of different interpretation of results. It is also the only method to directly determine the absolute configuration of chiral molecules. The chemical phase designations for samples 1, 2 and 3 taken from the viaduct are summarized in Fig. 9 **.**

In sample No. 1, **$Ca_3Si(OH)_6(CO_3)(SO_4)*12H_2O$** thaumasite was identified, which may reduce the durability of the concrete. In literature [16] it is stated that thaumasite is formed at relatively low temperatures from 0° C to +5°C, usually below 10°C. This is attributable to the existence of more favorable conditions for the formation of a transition phase containing groups $[Si(OH)_6]^{2-}$, that allow the formation of thaumasite compounds. The sulfate corrosion of the cement matrix starts with the interaction of sulfates with the participation of $CaCO_3$ or CO_2. Thaumasite then occurs in the form of an off-white powder that has no binding capacity. This is dangerous for the concrete destruction of hydrated calcium silicate, which, however, does not occur in this form in the cement matrix being tested. Thaumasite was identified in sample 1 in the layer directly in contact with the environment. thaumasite was not found in samples located 30-40 cm from the wall surface. The literature also states that due to the relatively low temperatures of thaumasite formation, favorable conditions for its appearance appear in the facilities of the communication infrastructure. Methods to reduce the risk of this type of corrosion speak of a classic approach, primarily limiting the permeability of concrete through, for example, hydrophobization, as described by the author in [16].

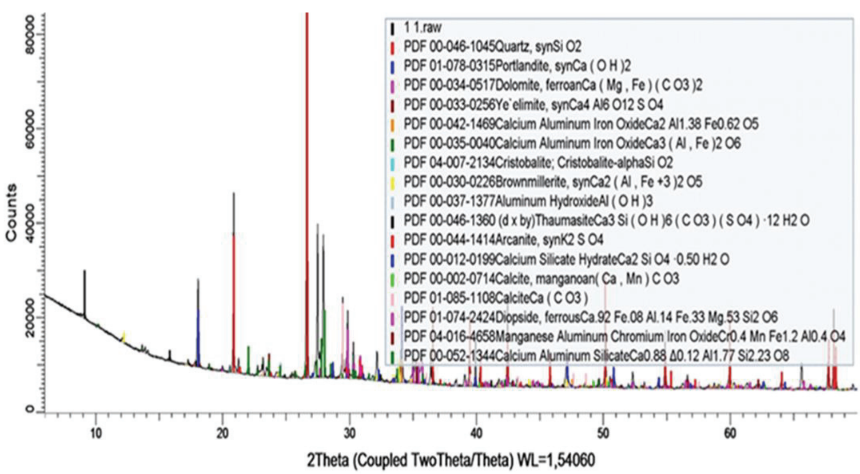


Fig.9. XRD analysis for sample No.1 taken from the near surface layer

4. CRITICAL ASSESSMENT OF THE LABORATORY METHOD FOR FROST RESISTANCE TESTING FOR CONCRETE AND ITS INFLUENCE ON LOWERING STRENGTH AFTER THE PROCESS OF CYCLIC FREEZING

4.1. AN ORIGINAL SUPPLEMENT TO THE CLASSIFICATION OF CONCRETE POROSITY

The phenomenon of frost resistance of concrete is related to its porosity and the possibility of breaking the capillaries by aerating the mixture. Research on this subject is widely known and the consequence is the classification of micro and nano discontinuities. The lists presented by IUPAC, P. Mechta (1986) and S. Mindess (2002) summarized in [18] are commonly known. The author's work done in 2017/2018 on the frost resistance of road and bridge concretes has shown, however, that as a result of specific technological processes related to the production of concrete mix for these objects, there are no previously identified types of the micro cracks marked in red in Table 2. Hence, the reasons for their occurrence are given in section 4 and in many other own publications [13,14,15].

4.2. Destructive effect of cyclic freezing – the Erlin/Mather effect

The Polish General Technical Specifications for concrete viaducts (also bridges) provide for testing the resistance of concrete to so-called frost "By the ordinary method" according to PN-B-06265.

Table 2. Supplemented by Author's classification of pores and features in concrete apart from known ones Capillary Pores, Gel Pores, Interlayer Spaces

Pores	Description	Size	Water	Technique[1)]	Properties
Capillary Pores	Large	10µm-50 nm	Evaporable Bulk water	SEM / OM	Permeability, strength
	Medium	50-10 nm	Evaporable Moderate menisci	SEM	Permeability, strength, shrinkage (high RH)
Gel Pores	Small	10-2.5 nm	Evaporable Strong menisci	Adsorption/ MIP/IS	Shrinkage (to 50% RH)
	Micro pores	2.5-0,5 nm	Non-evaporable No menisci Intermolecular interactions	Adsorption/ MIP/IS	Shrinkage, creep (35-11%RH)
Interlayer Spaces	Structural	< 0.5 nm	Non-evaporable Ionic/covalent bond	Adsorption/ Thermal	Shrinkage, creep (<11% RH)
Other Features	Special Micro cracks	1-5 µm	Bulk Water	SEM	Permeability, Strength Frost resistance
	ITZ	20-50 µm	Bulk Water	SEM/OM	Permeability, strength
	Microcracks	50->200 µm	Bulk Water	SEM/OM	Permeability, strength
	Entrained voids	50µm to 1 mm	Bulk Water	OM	Strength

[1)] SEM: scanning electron microscopy; OM: optical microscopy; IS: impedance spectroscopy

This standard has been subsequently withdrawn and replaced by the PN-EN 206-1 standard. In 2018, the national supplement to the standard PN-B-06265: 2018-10 to the standard PN-EN 206-1 was adopted, retaining the existing testing procedure for frost resistance and consisting of verification of the designed degree of frost resistance (F…) of emplaced concrete. Herein, the degree of hardiness of concrete corresponds to the N index, which is equal to the number of anticipated construction years, at least 150 (hence F150). This method allows taking into account both the degree of internal destruction of concrete, characterized by the strength of the control sample, as well as external destruction, determined visually and by the loss of mass of the sample. The appropriate degree of hardiness of concrete is achieved if, after the number of freezing / defrosting cycles of concrete samples required in its symbol, the following conditions are met:

- the samples do not show any cracks,
- the total mass of concrete defects in the form of damaged corners and edges, spatter, etc. does not exceed 5% of the mass of the samples before the start of the freezing/thawing cycles,
- reduction of compressive strength in relation to the strength of unfrozen samples is not greater than 20%.

The frost resistance tests carried out on numerous samples taken from road viaducts and implemented using the borehole method clearly show that micro cracks already exist in the cement matrix even before the freezing tests are carried out using the "usual method".

In the standard test procedure for frost resistance, with full water saturation, capillaries and micro cracks are filled with water. This, under temperature change testing causes cyclical freezing and thawing of the concrete that is described as a "micro ice lence pump" resulting from volume changes of the water-ice phase (written by Setzer [19], but described in Erlin/Mather [20] – and a recent theory among several others). As a result, the micro cracks spread, and, as a consequence, the concrete strength decreases despite proper aeration. Water phase changes are commonly accompanied by the appearance of white substances around or in the interior. Through analysis, it was found that these white substances are calcium derivatives and generally do not form destructive compounds like thaumasite or delayed ettringite.

The inference is based on water-ice phase change and changes in ice density in the temperature range -5°C to -50°C and the decrease of its volume in the same temperature range (see Fig 1 in [20] entitled: Response of water and ice in a capillary pore in cement paste as freezing temperature decreases - The Erlin/Mather Effect). Erlin and Mather [20] describe this process :

"*….as the temperature decreases, ice formed by water freezing in a capillary cavity in concrete will occupy a progressively smaller volume due to thermal contraction resulting from cooling. Other* *material present will also get smaller as it gets colder. If the capillary cavity is full, or more than 91% full of pore fluid, the initial volume increment of ice that forms is sufficient to overfill the cavity. That puts the remaining unfrozen liquid under hydraulic or hydrostatic pressure. That liquid will have a lower freezing point because it is under pressure and also contains solutes in solution, the concentration of which will increase as more ice is formed so the freezing point is progressively lowered. As the temperature continues to drop, some of that solution now becomes ice. Because the unfrozen fluid stays fluid until the freezing point drops to its reduced freezing point, it will be able to move into and occupy any increment of space made available by the reduction in volume of the ice as the temperature drops…*"

The process of concrete destruction described by these authors is shown in Fig. 10.

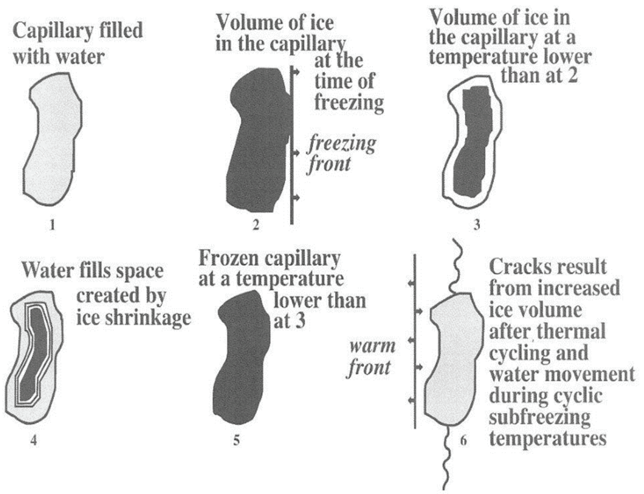


Fig.10. Response of water and ice in a capillary pore in cement paste at the freezing temperature decreases (Erlin & Mather, 2005, also in [20])

5. CONCLUSIONS

The article draws attention to the significant problem of some concrete bridge structures failing to meet the frost resistance criterion. It is also a summary of almost 10 years of the author's research on the explanation of the reasons for the lack of frost resistance of concrete in new road viaducts, the author of which in the years 2012 - 2018 analyzed more than 20 The problem was also widely discussed in the scientific community, but initially various other reasons were mentioned, not " congenital "micro cracks. The author's task is this aspect is the most important and this scientific work is devoted to this issue.

It seems that the issue is of a general character, and the lack of signals about this phenomenon from other regions of the world can testify to the occurrence of such situations only incidentally, so the problem did not get a broader study. In the past, explanation was provided through the *effect of delayed ettringite formation,* and this process was seen to occur in both in bridge structures and (but much later noticed) in the production of railway prestressed sleepers. There were also numerous clearly visible cracks on the occasion, but not evident during concreting, making an appearance only much later [4,8]. A similar view regarding the possibility of cracks on bridge structures was expressed by Divet and Pavoni [12]. The processes described in this article relate to micro cracks of bridges that were already evident during their por and curing and where the phenomenon of high loss of compressive strength of concrete was found to occur only after about 100 freezing - defrosting cycles in the temperature range – 18°C to + 18°C. Herein, the mature concrete was well aerated (A_{300} > 1.8%) and the micro cracks resulted from thermal processes, but not from improper aeration. For the destruction, the Erlin/Mather effect described in the article was found to be responsible.

A separate problem is the need for further operation of the viaduct structures with latent micro cracks. First of all, it was recommended to periodically inspect the structural elements and perform ultrasonic measurements in accordance with the developed curves strength, MPa and wave flow velocity, m/s. To protect against penetration, surface impregnation of concrete was recommended, which in some cases significantly reduced concrete frost losses.

For the future realization of concrete road viaducts, it was also recommended to change the cement so as to not encounter the Ye'elimite phases that are responsible for the high heat of hydration that causes the creation of micro cracks.

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LIST OF FIGURES AND TABLES:

Fig.4 Image of microcracks in bridge concrete made with the cement 52,5 R

Rys.4 Obraz mikropęknięć w betonie mostowym wykonanym z cementu 52,5 R

Fig. 5 Micro cracks of an unfrozen sample. Drawing (a): magnification 1000 x, observation field 200x200 μm. Drawing (b): magnification 5000 x, observation field 40x40 μm; width of the cracks from 1.08 to 1.65 μm

Rys.5 Mikrozarysowania próbki niezamrożonej. Rysunek (a): powiększenie 1000 x, pole obserwacji 200x200 μm. Rysunek (b): powiększenie 5000 x, pole obserwacji 40x40 μm; szerokość pęknięć od 1,08 do 1,65 μm

Fig. 6 Micro cracks of a frozen sample. Drawing (a): magnification 2000 x, observation field 100x100 μm. Drawing (b): magnification 5000 x, observation field 40x40 μm; width of the cracks between 2.61 and 3.69 μm

Rys.6 Mikrozarysowania próbki zamrożonej . Rysunek (a): powiększenie 2000 x, pole obserwacji 100x100 μm. Rysunek (b): powiększenie 5000 x, pole obserwacji 40x40 μm; szerokość pęknięć od 2,61 do 3,69 μm

Fig. 7 Micro cracks (a) and their filling (b)

Rys.7 Mikrozarysowania (a) i ich wypełnienie (b)

Fig. 8 Chemical composition of cracks from Fig. 7 – b. Note the very large amount of calcium and carbonates

Rys.8 Skład chemiczny pęknięć z rys. 7 - b. Zwraca uwagę bardzo duża ilość wapnia i węglanów

Fig. 9 XRD analysis for sample No. 1 taken from the near surface layer

Rys.9 Analiza XRD dla próbki nr 1 pobrane z warstwy przypowierzchniowej

Fig. 10 Response of water and ice in a capillary pore in cement paste at the freezing temperature decreases (Erlin & Mather 2005)

Rys.10 Przemiany wody i lodu w porach kapilarnych w zaczynie cementowym przy cyklicznym zamrażaniu (Erlin & Mather 2005)

Table 1. Recipe and basic technical data for C40 / 50 concrete bridge class, F150

Tablica 1. Receptura i podstawowe dane techniczne betonu mostowego klasy C40/50 i F150

Table 2. Supplemented by Author's classification of pores and features in concrete apart from known ones Capillary Pores, Gel Pores, Interlayer Space

Tablica 2. Klasyfikacja porów i ich wpływ na cechy betonu . Oprócz porów kapilarnych, porów żelowych, przestrzeni międzywarstwowej wprowadzono mikrorysy potwierdzone przez autora artykułu i skutki ich oddziaływań.

WPŁYW MIKROZARYSOWAŃ POJAWIAJĄCYCH SIĘ PODCZAS BETONOWANIA WIADUKTÓW DROGOWYCH NA ICH CECHĘ MROZOODPORNOŚCI

Słowa kluczowe : wiadukty betonowe, mrozoodporność betonu , mikrozarysowania, analizy SEM i XRD

STRESZCZENIE

W ostatnich latach w krótkim przedziale czasu wybudowano w Polsce setki betonowych wiaduktów drogowych. Ich charakterystyczną cechą było zastosowanie wysokiej klasy betonu zawierającego cement CEM I 42,5 (podpory i przyczółki) oraz CEM I 52,5 (przęsła). Budowano często w zimie, w okresie obniżonych temperatur powietrza.. Pomimo pozytywnych wcześniejszych testów laboratoryjnych beton przygotowany w warunkach budowy często nie osiągał zakładanej cechy mrozoodporności po 150 cyklach zamrażania-rozmrażania w zakresie temperatur od - 18 ° C do + 18 ° C.

Procesowi towarzyszyły nietypowe zjawiska.. Większy niż normatywny spadek wytrzymałości betonu następował przy jednoczesnej dużej szczelności. Brak było odprysków powierzchniowych typowych dla betonu o niskiej mrozoodporności, krzywizny krawędzi itp. Natomiast na powierzchni próbki wokół dużych ziaren kruszywa pojawia się charakterystyczna siatka mikrorys wypełnionych białymi wyciekami nieznanych związków chemicznych. Związki te zostały dokładnie przebadane za pomocą analizy SEM. Wcześniej podobny przypadek wystąpił w Polsce tylko raz, w 2002 roku . Światowa literatura przedstawia wiele przypadków związanych z zarysowaniami matrycy cementowej w wyniku na przykład opóźnionego ettringitu, także w mostach, ale analizowany w artykule przypadek jest inny, spowodowany „wrodzonymi" mikrozarysowaniami powstałymi już na etapie betonowania konstrukcji i późniejszej destrukcji podczas cyklicznego zamrażania w wyniku zjawiska opisanego w literaturze jako efekt erlina/mathera.

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