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Measurement of Frost Resistance of Cement Concrete with Fly Ash

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Abstract: Fly ash is due to its pozzolanic properties commonly used as the active component of concrete. This obviously has effect on the properties of the resulting material. One of the most important indicators of the quality of the material is its durability. The basic parameter of durability is a frost resistance. There are several approaches to measuring the frost resistance in the Czech Republic. This paper deals with a summary of these procedures and their pitfalls. Furthermore, the article provides examples of measurement – from the practice concrete of Orlik Dam. Literature shows the effect of fly ash on the frost resistance of the resulting concrete as ambivalent. When measuring the frost resistance of concrete with fly ash it is very important to take account of the measuring method, type of the fly ash and the degree of substitution clinker.

Keywords: Concrete; Cement; Fly Ash; Frost Resistance.

1 Introduction

Effective use of alternative materials is related also to the building industry. One such alternative material is fly ash. Fly ash is produced by burning coal in thermal power plants. One possible use of the fly ash in the building industry is substitution of clinker in concrete mixtures. Positive aspect is especially saving energy and money. Fly ash has an effect on durability. An important indicator of the durability of the material is the frost resistance. We have different methods for frost resistance measurement. Influence of fly ash on the frost resistance of concrete is ambivalent [1, 2].

2 Possibilities of Measurementof Frost Resistance

The frost resistance can be determined in various ways. The most frequently used procedure according to ČSN 73 1322 - Determination of frost resistance of concrete (1969) [3]. Specimens must be in the form of the beams with dimensions 100 × 100 × 400 mm and must be saturated. The samples are exposed during the test cycles freezing at -15 to -20 °C for 2 hours and thawing at +15 to +22 °C for 4 hours.The number of cycles is as needed 50, 100 or 150. The monitored parameters are - weight loss, change in tensile strength for bending and compressive strength. Coefficient of a frost resistance is derived from the ratio of the tensile strength of frozen and not frozen samples. Although it is the most frequently used approach, so major disadvantage associated with modern cements is that the tensile strengthin bending can increasein concrete during freeze-thaw cycles and thus the coefficient of the frost resistance can be greater than 1 [4]. An alternative to destructive testing frost resistance is the standard ČSN 73 1326 – Resistance of cement concrete surface to water and defrosting chemicals (1985) [5]. The main difference is that the test specimens are stored in NaCl. The weight of the wasteis measured during freeze-thaw cycles. The standard ČSN 73 1380 – Testing the freeze-thaw resistance of concrete - Internal structural damage (2007) [6] describes the non-destructive test method of the frost resistance. But this approach is not yet used too. The principle is to determine the relative change in the dynamic modulus of elasticity of specimens after freeze-thaw cycles based on the transit time of ultrasonic pulses or a transverse frequency. The disadvantage, however, is the absence of the evaluation criteria and the length of the freezing cycle of 12 hours [7].

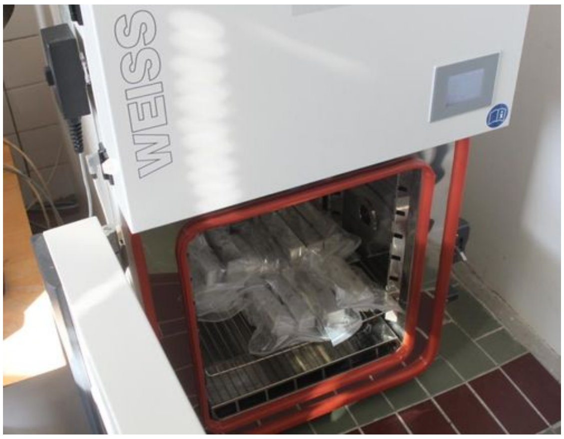

Fig. 1: Climatic chamber of the firm Weiss with specimens of cement-fly ash composites prepared to freeze cycles.

Fig. 2: Measurement system for dynamic modulus determination.

In Fig. 1 is seen climatic chamber where the test of frost resistance can be performed. In Fig. 2, there is the measurement system for determination of dynamic modulus of elasticity. The Frequency Response Function (FRF) was calculated based on the measured impact force and the response. The resonant frequencies were determined from FRF and then the dynamic modulus was calculated based on these frequencies, weight and dimensions of the specimen [8].

3 Measurement of Frost Resistance of Cement Concrete with Fly Ash in Practice

The first practical example is the concrete of the dam Orlik. This significant construction was constructed between 1956 and 1961 (Fig. 3 and 4). The concrete of the dam body does not have a classic composition. Cracking of concrete was caused by the rapid increase in the heat of hydration in the beginning of construction. Substitution of a clinker fly ash was chosen as a solution to this problem. The concrete had two different mixtures, in the packaging concrete was replaced 20 % by weight of cement and concrete core 28 % by weight of cement with fly ash.

Fig. 3: Gravity dam's body of the dam Orlik.

Fig. 4: Shaft of the dam Orlik.

Tab. 1: Characteristics of specimens [9].

designation of specimens [-]	shape [-]	dimension [mm]	weight in concrete [kg/m^3]	
			cement	fly ash
B1	cube	200	250	0
B2	beam	100/100/500	200	50

Of about 20.000 control tests were done in situ and in the laboratory during the construction. The frost resistance was of course also monitored. Two kinds of specimens were produced and the changing of compressive and tensile strength was monitored. In Tab. 1 there are characteristics of specimens and Tab. 2 shows the strength after 150 freezing cycles [9].

Tab. 2: Average strength before/after 150 freeze-thaw cycles [9].

designation of specimens [-]	average strength [MPa]					
	compressive			tensile		
	not frozen	frozen	decrease [%]	not frozen	frozen	decrease [%]
B1 (after 90 days)	30.7	28.9	5.9	-	-	-
B2 (after 28 days)	26.6	24.1	9.4	4.6	3.5	23.4

Tab. 3 shows next examples from practice. There arevarious buildings and one experiment in USA and Canada. There is for example parking or bridge. The concrete has different age and different substitution of cement with fly ash. From Tab. 3, it can be seen that old age is not for the frost resistance an affecting parameter. A substantial factor, however, is degree of substitution with fly ash.

Tab. 3: Frost resistance of constructions of concrete with different content fly ash in USA and Canada [10].

locality [-]	age [years]	content fly ash in concrete* [%]	status description		
			very good	satisfactory	unsatisfactory
Kingston (experiment)	6	18	•		
Wisconsin (Sussex) I	6	40	•		
Wisconsin (Sussex) II	5	50		•	
Wisconsin (parking) I	4	48	•		
Wisconsin (parking) II	4	52			•
Michigan (bridge) I	20	14	•		
Michigan (bridge) II	20	20	•		
Michigan (bridge) III	5	60			•

* substitution of weight cement with fly ash

4 Conclusion

Fly ash has an ambivalent effect on the frost resistance of the resulting concrete. The frost resistance of the concrete depends on the type of a fly ash and amount of a clinker substituted by the fly ash. Age of concrete does not have affect to the frost resistance. For this parameter, it appears to be the optimum value of substitution of about 20 % by weight of clinker. Analysis of the concrete of the Dam Orlik shows that concrete with almost 30 % of fly ash has excellent quality after more than 50 years in operation [11].

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