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INFLUENCE OF TEMPERATURE ON WORKABILITY AND COMPRESSIVE STRENGTH OF ORDINARY CONCRETE WITH HIGHCALCIUM FLY ASH

Abstract

The rheological properties of fresh ordinary concrete are closely affected by temperature and time. The paper presents the study of consistency of fresh concrete mixtures made with Portland cement and cement with calcareous fly ash. Two types of admixtures were used. It was proven that the temperature has a clear effect on workability and compressive strength concrete. Influence on workability can be reduced by selecting the appropriate superplasticizer and cement.

Keywords

Fresh concrete, workability, temperature, high calcium fly ash.

1 INTRODUCTION

Temperature is a factor inextricably linked to the processes of mixing and casting of concrete. The final temperature of the fresh concrete is influenced by a temperature of the component, ambient temperature, and the heat generated by the mixing. Under real conditions ensuring the same temperature of the mixture is very problematic and in fact this can be done only in the case of the precast production. Effect of temperature on the workability of ordinary concrete is well recognized.

The mechanism of effect of temperature on workability of ordinary concrete without chemical admixtures is connected to the cement hydration process, which speeds up with the raise of temperature. The factor which additionally hastens the loss of workability in higher temperatures is the loss of water due to its evaporation. When chemical admixtures are introduced to the concrete mixture, the effect of influence of temperature on workability becomes more complex. This is due to the mechanism of action of chemical admixtures, in particular the process of adsorption of the admixtures on the grains and products of cement hydration. Process of adsorption itself is dependent on the temperature in which the hydration occurs. Additionally, the change of temperature in which the process of cement hydration occurs leads to quantitative and qualitative change in the structure of cement paste, what in turn results in the differentiation of the hydration products, each of which adsorbs the admixtures differently. The higher its adsorption degree on the grains and hydration products, the higher is the effectiveness of the admixture.

The influence of temperature on the mechanical properties in case of presented strength research is dependent on two mechanisms. First is connected to the influence of temperature on the workability – worse workability will result in lower strength. The second mechanism is connected to

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the influence of temperature on the speed of hydration and the structure of the cement paste. It is common knowledge, that the higher temperatures cause the faster increase of strength, especially in the initial phase of hardening. Lower temperatures, in turn, have opposite effect, however, it is common for the late strength to be higher for concretes made and hardening in lower temperatures.

Concrete without chemical admixtures are nowadays a rarity, if they are even used at all. In their case the lowering of the susceptibility for temperature can be obtained by appropriate selection of cement. In fresh concrete with admixtures it is necessary to choose the right cement and appropriate admixture. There are more possibilities, but the amount of phenomena affecting the influence of temperature increases. This causes ensuring the resistance to changes in temperature to be more difficult, but not impossible [1].

2 METODOLOGY OF RESEARCHES AND PROPERTIES OF MATERIALS

Fresh concrete were made from preheated or pre-cooled constituents, so that the temperature of mixture would be 10, 20 and 30°C. The consistency of the concrete mixtures was determined by the flow table test according to standard EN 12350-5. Consistency tests were conducted after 5 and 60 minutes from the moment of adding the water to the concrete mixtures. Mixing time amounted to 3 minutes. Between the measurements the mixtures were kept covered in climate room, and were remixed before second measurement. The compressive strength was tested after 2, 7, 28 and 90 days of hardening. The set temperature of the concrete mix (10, 20 or 30 °C) was maintained during the first 24 h after mixing, then the samples were hardening in water of temperature 20°C.

Concrete were made on the creek rock aggregate with fractions up to 8 mm. The aggregate grading curve is shown in Fig. 1. The concrete mixtures were made with Portland cement CEM I 42.5R and cements with an addition of fly ashes. The compositions and properties of the binders are presented in tab. 1, 2, 3. Cements with addition of calcareous fly ashes were made by co-grinding of the clinker and calcareous fly ashes. Concrete compositions are shown in tab. 4.

Tab. 1: Chemical properties of cements

Cement	LOI	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	Na^2O_{eq}
	[%]						
CEM I 42,5R	1.90	20.85	65.56	4.60	2.1	0.92	0.26
CEM II/A-W	2.01	22.38	61.29	6.60	8.71	3.07	3.31
CEM II/B-W	2.19	23.89	56.56	8.71	3.07	1.19	0.26
CEM IV/B-W	2.76	32.12	42.93	12.35	3.31	1.17	0.23

Tab. 2: Physical properties of cements

Cement	Density [g/cm^3]	Water demand [%]	Time of setting [min]		Specific surface area [cm^2/g]
			begin	end	
CEM I 42.5R	3.10	25.8	135	180	3810
CEM II/A-W	3.04	27.6	153	263	4190
CEM II/B-W	2.98	30.4	180	250	4030
CEM IV/B-W	2.88	34.6	280	420	4200

Tab. 3: Content of cements

Cement	Portland clinker	Gypsum	Calcareous fly ash
	[%]		
CEM I 42.5R	97.0	3.0	-
CEM II/A-W	81.1	4.6	14.3
CEM II/B-W	67.7	3.3	29.0
CEM IV/B-W	48.0	4.0	48.0

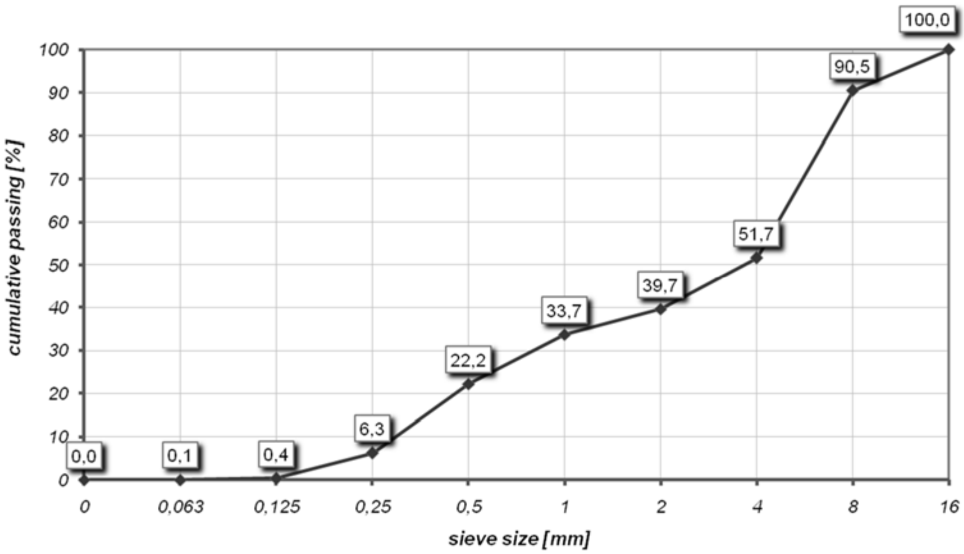

Fig.1: Aggregate trading curve

Tab. 4: Composition of concrete for 1 m^3

Constituent	Concrete without admixture	Concrete with plasticizer	Concrete with superplasticizer
Cement, kg	350	350	350
Sand 0-2, kg	688	687	728
Coarse aggregates 2-8, kg	1063	1061	1125
Plasticizer Chryso V70, kg		3.5	
Superplasticizer FM 30, kg			10.5
W/C ratio	0.6	0.6	0.45
Cement paste content, dm^3	339	340	301

3 RESULTS

In tables 4,5,6,7 are listed the results of consistency tests of ordinary concrete mixtures without admixtures, with plasticizer and superplasticizer. The increase of temperature causes the reduction of the flow diameter of the concrete mixtures. In some cases the changes are significant and lead to changing the classification of the concrete mixtures in terms of consistency. The big changes on mixture consistency affect its workability. If the workability loss is not compensated by the adequate compaction, it can lead to higher air content, what in turn leads to lower compressive strength. The concrete mixtures for which the change of temperature leads to better workability, can segregate due to the incorrect compaction. This can lead to the defects in concrete structure, what can decrease concrete durability.

Tab. 5: The flow diameter of fresh concrete without admixtures and their class of consistency according to EN 12350-4

Cement	time [min]	10 °C		20 °C		30 °C	
		R [cm]	Class	R [cm]	Class	R [cm]	Class
CEM I 42,5 R	5	48.0	F3	43.0	F3	39.0	F2
	60	44.0	F3	39.0	F2	33.0	F1
CEM II A-W	5	45.5	F3	41.0	F2	38.0	F2
	60	40.0	F2	37.5	F2	33.5	F2
CEM II B-W	5	43.5	F3	36.0	F2	33.0	F1
	60	38.0	F2	34.0	F1	30.0	F1
CEM IV B-W	5	40.0	F2	35.0	F2	29.0	F1
	60	36.0	F1	32.0	F1	27.0	F1

Tab. 6: The flow diameter of fresh concrete with plasticizer Chryso V70 and their class of consistency according to EN 12350-4

Cement	time [min]	10 °C		20 °C		30 °C	
		R [cm]	Class	R [cm]	Class	R [cm]	Class
CEM I 42,5 R	5	56.0	F5	52.0	F4	41.0	F2
	60	49.0	F4	46.0	F4	38.5	F2
CEM II A-W	5	57.0	F5	52.0	F4	47.0	F3
	60	51.0	F4	45.0	F3	44.0	F3
CEM II B-W	5	59.0	F5	55.0	F4	51.0	F4
	60	53.0	F4	46.0	F3	45.0	F3
CEM IV B-W	5	54.0	F4	47.0	F3	43.0	F3
	60	48.0	F3	45.0	F3	39.0	F2

Tab. 7: The flow diameter of fresh concrete with superplasticizer FM 30 and their class of consistency according to EN 12350-4

Cement	time [min]	10 °C		20 °C		30 °C	
		R [cm]	Class	R [cm]	Class	R [cm]	Class
CEM I 42,5 R	5	59.0	F5	53.5	F4	51.0	F2
	60	52.0	F4	53.0	F4	50.0	F2
CEM II A-W	5	56.5	F5	55.5	F4	45.0	F3
	60	46.0	F4	46.0	F3	35.5	F3
CEM II B-W	5	56.5	F5	52.5	F4	41.0	F4
	60	40.0	F4	38.5	F3	34.5	F3
CEM IV B-W	5	45.0	F4	43.0	F3	30.0	F3
	60	38.0	F3	33.0	F3	28.0	F2

To synthetically evaluate the susceptibility of tested concrete mixtures in aspect of the influence of temperature on workability, the paper introduces the index of temperature's influence on concrete mix consistency R_t calculated according to the formula (1)

$$R_t = \left(1 - \frac{R_{min}}{R_{max}}\right) \cdot \left(\frac{R_{20} - R_{min}}{R_{max} - R_{min}}\right) \quad (1)$$

where:

R_{max} – Maximal flow diameter of the concrete mixture in tested temperature range,

R_{min} – minimal flow diameter of the concrete mixture in tested temperature range,

R_{20} - flow diameter of the concrete mix in temperature of 20 °C

Higher value of R_t characterized concrete mixtures with lower resilience on the temperature changes. Also, it is higher for the concrete mixtures for which the temperature change causes greater negative changes of workability. This is included by the second factor of the equation which defines the index R_t. In Fig. 2 and 3 are shown the values of R_t for fresh concretes.

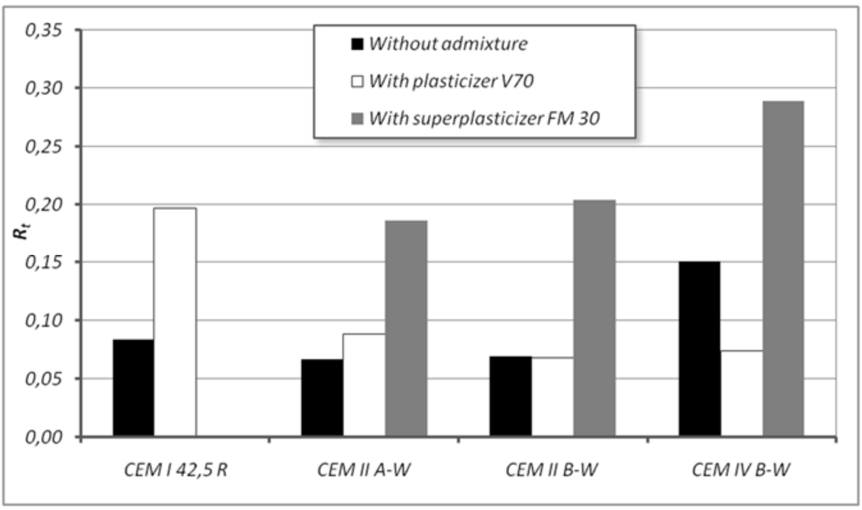

Fig. 2: Index R_t for consistency of fresh concretes tested 5 minutes after the start of mixing

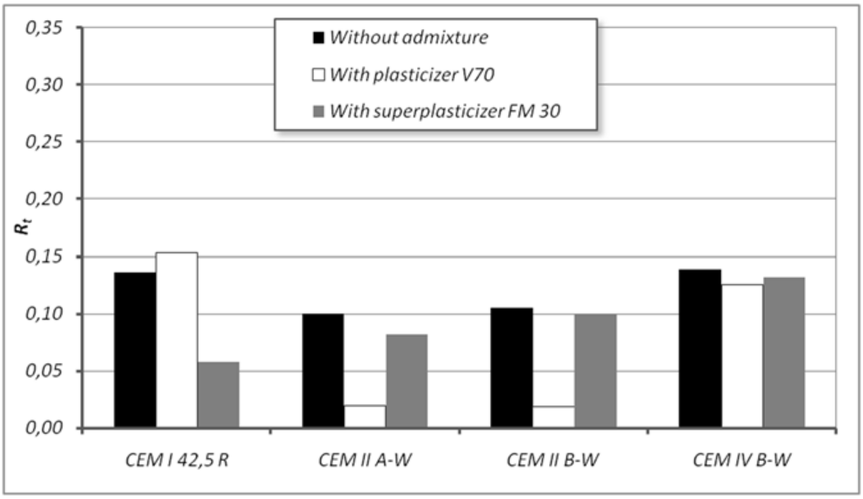

Fig. 3: Index R_t for consistency of fresh concretes tested 60 minutes after the start of mixing

The susceptibility of concrete mixtures to changes of consistency due to the temperature in case of ordinary concrete is dependent on the type of binder and/or admixture. Immediately after the end of mixing process, index R_t of the concrete mixtures with Portland cement and cements with an addition of CFA up to 30% (CEM II A-W and CEM II B-W) has similar value. Only CFA content of 50% causes the concrete mix to be more susceptible to workability loss caused by increased temperature. Concrete mix with Portland cement and plasticizer Chryso V 70 is the most susceptible to the workability loss caused by increase of temperature, but with superplasticizer FM 30 its consistency is not dependent on the temperature. After 60 minutes the influence of the temperature can be considered to be minimal. Using the superplasticizer FM 30 in concrete mixtures with cements with calcerous fly ash results in significant raise of the negative influence of temperature on the workability of the concrete mixtures. This influence increases with the increase of fly ash content in the concrete mixture. After 60 minutes the influence of temperature on the concrete mixture consistency is the lowest for the concrete mixtures with admixture Chryso V 70 and cements CEM II A-W and B-W. The influence of the temperature on concrete mixture for concrete mixtures with FM 30 is the higher, the higher is the fly ash content.

The temperature of concrete mixture affects the compressive strength – in the research the temperature of 10, 20 or 30 °C was maintained only during first 24 h of hardening. The figures 4,5,6 and 7 show the influence of temperature on the compressive strength tested after 2, 7, 28 and 90 days of hardening in water in temperature 20 ºC. The significant influence of the temperature of the concrete mixture on compressive strength can be observed. It is more pronounced in the early stages of hardening. During the hardening, differences between the compressive strength of concrete mixtures in temperatures 10, 20 and 30°C are becoming smaller. However, after 28 days of hardening the differences between compressive strength can be high enough to place the concretes in different strength classes. Lower compressive strengths characteristic for lower temperatures require formworks for construction for a longer time.

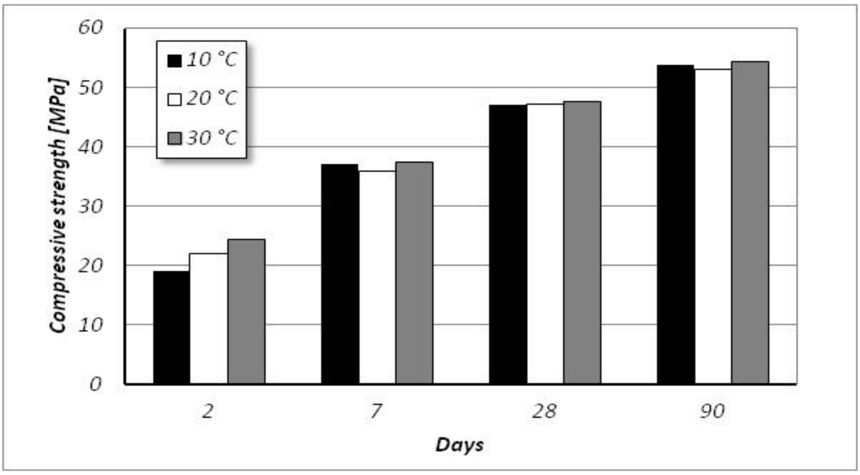

Fig. 4: Compressive strength of concrete with cement CEM I 42,5 R (without admixture)

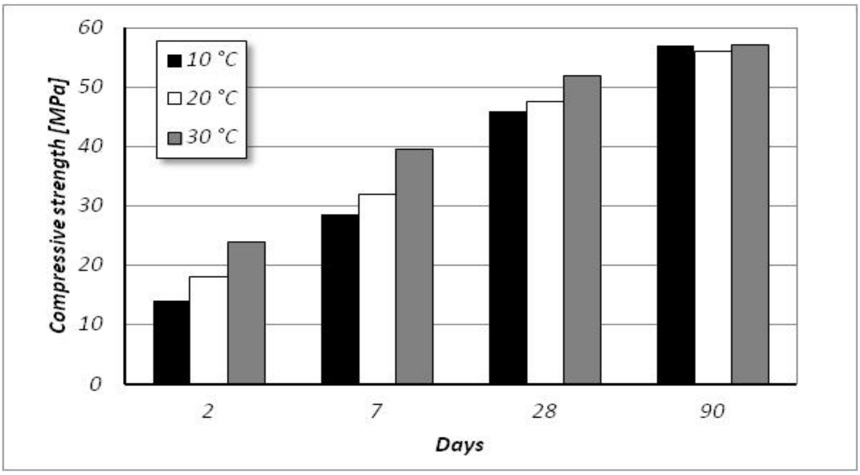

Fig. 5: Compressive strength of concrete with cement CEM II/A-W (without admixture)

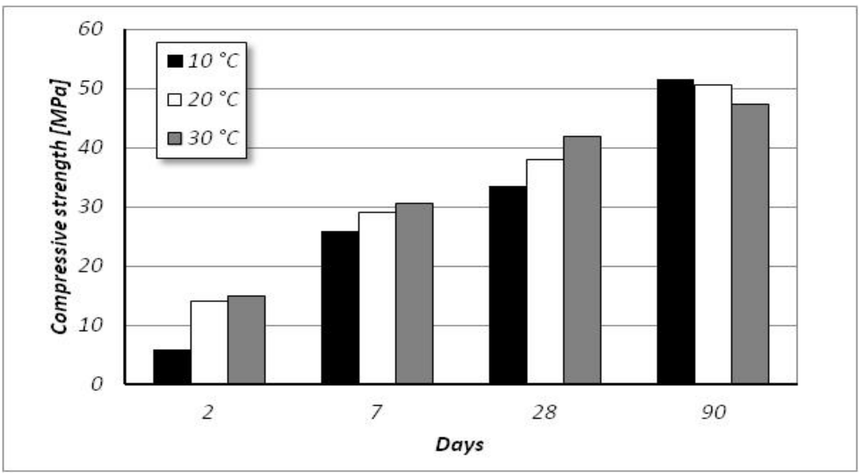

Fig. 6: Compressive strength of concrete with cement CEM II/B-W (without admixture)

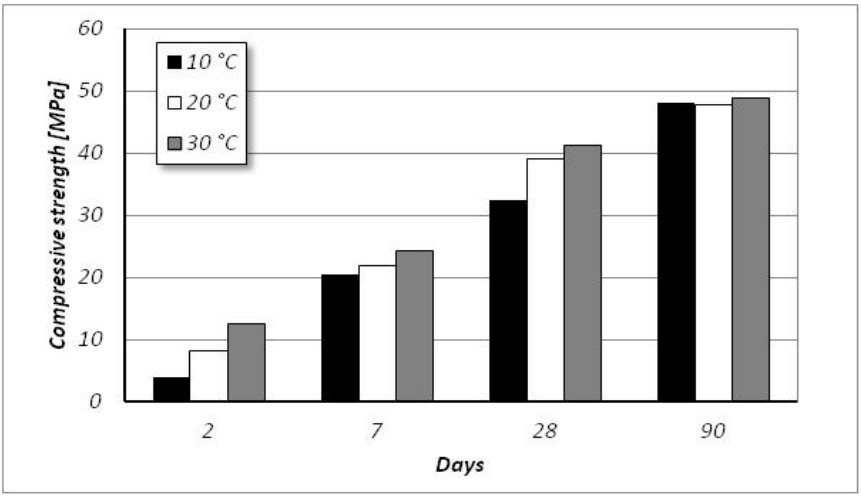

Fig. 7: Compressive strength of concrete with cement CEM IV/B-W (without admixture)

4 CONCLUSIONS

The influence of temperature on the workability of ordinary concrete manifests itself by decrease of the flow diameter in higher temperatures. This influence can be minimized by selecting appropriate admixtures and cements. Due to the labour intensity and material consumption of the laboratory work connected with the research into the influence of temperature on concrete workability (necessity of cooling or heating up the large quantity of materials), it is convenient to conduct this type of research on mortars, which composition can be determined according to the procedure presented in [2]. A mortar designed according to that method exhibits a compatibility with the behaviour of concrete mixture in the system of variable technological factors. Temperature of the concrete mixture influences the compressive strength of concrete. Its influence is so pronounced, that it can require the different classification of the concrete in terms of strength.

LITERATURE

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