Low-Carbon Blended Cement with High Content of Supplementary Cementitious Materials

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This paper considers physical and mechanical properties of low-carbon blended cements with content of supplementary Cementitious materials 50 wt.% It is shown that due to the synergistic combination of blast furnace granulated slag, zeolite and limestone compressive strength of low-carbon blended cement is obtained class 32.5 with high early strength.

Keywords – low-carbon blended cement, supplementary Cementitious materials, compressive strength.

Introduction

Climate change and global warming represent a serious problem as level of greenhouse gas emissions are still high - 32.5 Gt. CO_2 emission of the cement industry is 1,6-2.6 Gt or 5-8 % of the total amount of anthropogenic emissions worldwide [1]. It is necessary to realize by 2050 a global strategy of low-carbon development in order to prevent the temperature rise on the planet to a level significantly less than 2 ^{0}C in keeping with requirements of the Paris Agreement on the United Nations Framework Convention about Climate Change (UNFCCC) on the regulation of measures to reduce carbon dioxide emissions from 2020 [2]. Concept of sustainable development has spurred renewed interest in reducing the content of Portland cement clinker in cement binder by replacing it with supplementary Cementitious materials (SCMs), including waste industry [3, 4]. Production of blended cement according to EN 197-1 creates prospects for improving the efficiency of binder due to the possibility of reducing the content of Portland cement clinker and increasing the amount of SCMs.

Materials and methods

Ordinary Portland cement (OPC) CEM I 42,5R JSC "Ivano-Frankivsk Cement" composed of C_3S: 62.42, C_2S: 13.62, C_3A: 7.06, C_4AF: 12.32, wt %, limestone (L) with 95 wt % $CaCO_3$, granulated blast furnace slag (GBFS), zeolite (Z) provided from Sokyrnytsky quarry were used to develop the composition of low-carbon blended cement. The Blaine specific surface areas of OPC, GBFS, zeolite and limestone were 3400; 3680, 9940 and 10500 cm²/g.

The cements were obtained by mixing together in a laboratory ball mill. The specific surface areas of the components of the binder, as the resulting compositions of cements, were determined by Blaine. The cement mortars for determination the Strength class of cements was prepared on the basis of the investigated binder in a one part and standard sand CEN in a three parts and half part of water.

Experimental part

In order to determine the influence of the each SCMs in the composition of the cement, blended cements were prepared – containing 50 wt. % of one type of additive. For OPC i (SSA=3400 cm^2/g) workability is 165 mm with W / C = 0.5. Replacement 50 wt. % OPC with GBFS is causing increase SSA and consistence respectively to 3730 cm^2/g and 175 mm. Zeolite in the amount of 50 wt. % increases the SSA of the cement to 6370 cm^2/g, while the workability decreases to 117 mm, while the same amount of limestone increases the dispersion to 7990 cm^2/g with a decrease in the consistence of the mixture only to 160 mm. In the combination of the investigated SCMs in the corresponding quantity received a blended composition cement CEM V / A (SSA=6000 cm^2/g) and its consistency by the workability is 155 mm.

OPC is characterized by water demand 31.7% and initial and final setting time respectively 235 and 340 min. Water demand of cement with content of 50 wt. % GBFS is 27.5% and the setting time are delayed for 20 min. Zeolite increases the proper water amount to 38.5% with a decrease initial and final setting time respectively to 195 and 215 min. Limestone (50 wt. %) in the composition of the binder allows to reduce the water demand of the cement paste to 26 % and the initial and final setting time to 155 min and 215 min. Blended cement (SSA=6000 cm^2/g) is characterized by water demand 31%, initial and final setting time respectively 180 and 280 min.

It is shown, that the content of 50 wt. % SCMs leads to a decrease the compressive strength of cement during the all Harding period. As seen in Table 1, compressive strength of blended cement after 2, 7 and 28 days of hardening is 10,7, 19,7 and 38,0 MPa respectively. Result of research shown that blended cement has high early strength. The low-carbon blended cement complies to class CEM V/A 32.5 DSTU B EN 197-1:2015. This cement is characterized by homogeneity and a stability of the mix without sedimentation, the bleeding of composite cement paste is 15.3%. The lowering clinker factor ratio in CEM V/A 32.5 reduces the CO_2 discharge in the cement production process in 2 times/ 1 ton of cement.

Table 1

Physical and mechanical properties of cements

Main constituents, wt. %				Work-ability, mm	Compressive strength, age, MPa				SAI, %			
OPC	GBFS	Z	L		2	7	28	90	2	7	28	90
100	-	-	-	165	21,5	30,1	43,5	51,0	100,0	100,0	100,0	100,0
50	50	-	-	175	5,7	17	31,3	40,6	26,5	56,4	72,0	79.6
50	-	50	-	117	3,8	16	28,6	36,9	17,6	53,1	65,7	72.3
50	-	-	50	160	5,2	11	17,7	24,5	24,1	36,5	40,6	48,0
50	25	20	5	155	10,7	19,7	38,0	46,6	49,7	65,4	87,3	91.3

Blended cement with high content of SCMs is characterized by low energy consumption and meets the requirements of the modern building industry and the concept of sustainable development.

Conclusion

It is shown that due to the synergistic combination of blast furnace granulated slag, zeolite and limestone with increased dispersion the compressive strength of low-carbon blended cement refers to class 32.5 with high early strength. Using of blended cements with high early strength provides resource and energy saving, ecological and economic effects in construction, and also makes a significant contribution of the World strategy low-carbon development**.**

References

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