UDC691.327.3

Ash as an effective additive in the manufacture of concrete and reinforced concrete structures and products

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Аңдатпа. Жаңа болмыс жағдайында бетондағы қоспалардың болуы өзекті мәселе болып саналады. Жаңа тиімді жергілікті материалдардан жеңіл бетондарды пайдалану негізінде темір-бетон конструкцияларының тиімділігін арттыру құрылыс инфрақұрылымын дамытудың факторы болып табылды. Материалдарды зауытта дайындау, көлік шығындары мен ғимараттарды тұрғызу мерзімдері, материал сыйымдылығы мен еңбек сыйымдылығының азаюы конструкция салмағын төмендету есебінен қамтамасыз етіледі.

Кілт сөздер: *Бетон қоспалары, жергілікті материалдар, бетон, күл, Жылу энерго орталық (ЖЭО), Жылу энерго станция (ЖЭС).*

Аннотация. В условиях новой реальности актуальной проблемой выступает наличие добавок в бетоне. Повышение экономичности железобетонных конструкций на основе использования легких бетонов из новых эффективных местных материалов является одним из факторов развития инфраструктуры строительства. Уменьшение материалоемкости и трудоемкости их заводского изготовления, транспортных расходов и сроков возведения зданий обеспечивается за счет получаемого снижения веса конструкций.

Ключевые слова: *Добавки в бетоне, местные материалы, бетон, зола, Тепло энерго централь (ТЭЦ), Тепло энерго станция (ТЭС).*

Abstract. In the new reality the actual problem is the availability of additives in concrete. The effectiveness increase of the reinforced concrete structures through the use of lightweight concrete of new effective local materials is one of the factors in the development of infrastructure construction. Reduction of material consumption and complexity of their prefabrication, transport costs and construction time of buildings is ensured by the resulting weight of the structures.

KeyWords: *Additives in concrete, local material, concrete, ash, Thermal Power Plant (TPP), Central Heat Plant (CHP).*

Progress in construction largely depends on further increase of economy of reinforced concrete structures, including through using of lightweight concrete of the new efficient local materials. Obtained weight reduction of structures while providing a decrease in consumption of materials and laboriousness of their prefabrication, transportation costs and the timing of construction of buildings. Currently, the presence of additives in concrete - even more important problem than the consumption of cement. In domestic practice, mainly used in chemical and mineral supplement (alone or in the form of complexes), which is connected with simplicity of their injection due to the low dosage. The use of mineral additives to be incorporated in large amounts (50-200 kg/m^3), has today unfortunately very limited, despite a number of positive technical effects and undoubted economic benefits, but for the basic supplements - TPP and CHP plants ash is very important also for ecological positions. The projected deficit of cement in Kazakhstan - one more argument in favor of mineral supplements. In world practice, ash of TPP introduced in the vast majority of concrete and considered by many experts as their obligatory component [1].

This article presents the technological aspects of the experience of the ash in the production of concrete and reinforced concrete structures and products in Kazakhstan.

Introduction of ash in the concrete mix possible in different ways, for example instead of cement or instead of sand. Thus, introduction of ash instead of cement, results in reduced of strength. More efficient introduction of ash instead of sand: if the ash is effective - the strength is growing. In practice, the strength is usually required to keep at a constant level, in this case the ash replaces the cement, and a part - sand. The proportions of replacing depends on the effectiveness of of ash, which quantitatively can be expressed by efficiency coefficient (Ce). It has a clear physical meaning: the mass relation of abbreviated cement and input of ash, in which the strength of concrete remains constant. By using Ce easier and obvious assignment of the composition of concrete with ash. So, Ke=0.5 means that the conduct in the concrete, for example, 100 kg of ash to preserve the strength of cement consumption should be reduced by 50 kg and 50 kg - consumption of sand (when changing weight). In addition to pozzolanic effect ash has on concrete and significant physical effect which is called "effect of micro-filler". In pure form it appears to increase the strength with the introduction of concrete inert powders, for example, ground sand, pulverized waste crushing etc. In addition to pozzolanic effect ash has on concrete and significant physical effect which is called "effect of micro-filler". In pure form it appears to increase the strength with the introduction of concrete inert powders, for example, ground sand, pulverized waste crushing etc.

According to GOST 25818-91 quality indicators of TPP’s ash must requirements specified in table 1 [2].

Table 1: The quality indicators of TPP's ash

№ pos.	Name of Indicator	Value of Index
1	The content of calcium oxide (CaO), % by mass:	10
2	The content of magnesium oxide (MgO), % by mass, not more	5
3	The content of sulfur and sulfate compounds in terms of SO % by mass, not more:	3
4	The content of alkaline oxides in terms of NaO, %, by mass, not more:	3
5	Mass loss on ignition (p. p. p.), % by mass, not more:	20
6	Sieve residue N 008 % by mass, not more	20

When selecting the composition of the concrete should take into account bulk density, true density and specific surface area of ash. Table 2 shows the indices of bulk density and true density of some evils TPP Kazakhstan [3].

Table 2: Characteristic CHP's ashes of Kazakhstan

№ п/п	Power station	Bulk density, кg/м^3	True density, кg/м^3	Specific surface, м^2/кg
1	Ekibastuz CHP	960	2840	97
2	AlmatinskayaHPP	590	2110	432
3	Almatinskaya CHP	-	2150	389
4	Ust-Kamenogorsk CHP	870	-	-
5	Semipalatinskaya CHP	590	-	-
6	Kzyl - Orda CHP	870	2110	230
7	Ermakovskaya HPP	660	2070	184
8	Omsk CHP -4	590	1980	263

In the future ash will be obtained from combustion of Ekibastuz coals. To determine the positive effects on technical characteristics of concrete as a mineral Supplement use of ash from combustion of Ekibastuz coals. Analysis of literature data shows that Ekibastuzskie coals are more multiplex. The average ash content of coal is 40-50 %, indicating a significant content of mineral impurities. In ashes Ekibastuzsky coal contains (%): SiO_2 and Al_2O_3 is more than 80, Fe_2O_3 and FeO – 8, MgO 1.5, CaO – 2, the other oxides in minor amounts.Unlike other additives the ashes in three ways affects the properties of concrete. First, it acts as filler, making the concrete more dense. Second of all spherical form of the particles of the ash gives it a property called "ball bearing effect", which improves the sliding of cement and sand on the surface of the glassy particles of ash. Thirdly, fly ash significantly improves the strength of concrete, due to the so-called pozzolanic reaction (the hydraulic activity of ash), which interact with contained in the ash is amorphous silica and aluminum oxide c with calcium hydroxide formed during hydration of cement, forming calcium-silicate-hydrate phase (CSH-phase) [4]. The compressive strength of concrete is determined sizeofimage directly after production of the control cylinder. Test c produced a precision of 0.001 MPa. Testing can be carried out on any press, is suitable for measuring small strengths (for example, to determine the strength of cement prisms in flexure). The results of experimental data given in table 3.

Table 3: Results of experimental

Characteristics of concrete mix					**Results of tests**		
PC 500 кg/м^3	PC 400 кg/м^3	Ash кg/м^3	Water consumption l/м^3	Water / cement attitude	Pore volume %	Strength of freshly molded concrete, MPa	Strength in 28 days, Мпа
240	120	-	130	0,36	5,1	0,485	77,9
240	-	120	120	0,33	2,3	0,422	77,3

With the help of the conducted research was able to establish that the dependence of the strength of concrete sizeofimage of the density of the compacted semi-dry concrete mixture, strength at 28 days of age and Vodovozova relations minor.

The optimum additive amounts of ash can lead to an increase in strength sizeofimage concrete. This is due to the improvement of workability of semi-dry concrete mixes and, consequently, a decrease in pore volume.

In the course of experimental work carried out optimization of semi-dry concrete mixes using ash (table 4).

Table 4: The results of experimental data of concrete with supplement

№ pos.	**Name of Indicator**	**Results of tests**			
		Without ash	**With ash**	**Without ash**	**With ash**
1	Amount of ash, кg/м^3		50	70	90
2	Compressive strength at 28 days of age	68,7	69,1	66,4	61,9
3	The density of concrete at 28 - day age, kg/m3	2331	2309	2312	2317
4	Reducing the consumption of cement, kg/m3		70	90	120

The composition of the concrete was optimized so that the ash content of 70 kg/m^3 amount of Portland cement M500 In a 42.5 strength class has been reduced to 90 kg/m^3. The total number of cement binder (cement and fly ash) has been reduced by 20 kg/m^3.

At the same time the pore volume of the compacted semi-dry concrete mix has been reduced to 3.6 c to 5.3 percent.

The use of ash as an additive in the manufacture of semi-dry concrete mix contributes to a significant improvement of its workability and reduction of pore volume. Strength of fresh molded concrete and strength of concrete products in the design age the increase due to use of ash. The reason for this is optimal spherical form, the advantageous particle size distribution and pozzolanic properties of the ash.

Instead of control of compressive strength at 28 days of age standards require verification of semi-dry concrete mix strength at cracking and tensile in bending. Checking exposed to 8 compounds, the durability of each of which shall not be less than 3.6 MPa, a ultimate breaking load not less than 250 MPa. The above proves our statement that the use of optimal quantities of ash, regardless of the regulations and control methods, contributes economically and technologically advantageous production of semi-dry concrete mixes.It is known that high temperature greatly accelerates the kinetics of the reactions during the concrete curing process. This is especially true for ash containing concrete. Through the heat treatment accelerates the hydration process in concrete, significantly increases the rate of pozzolanic reaction of ash, which leads to accelerated formation of compounds of calcium hydrosilicates.

Table 5: The relative compressive strength of ash containing semi-dry concrete mixes after 6-hour heat treatment

Cement		**Ash, % frommass**	**Relative compressive strength, %**
Marking	% from mass		
Mixture 1	75	25	73,7
Mixture 2	75	25	77,1
Mixture 3	75	25	81,3

For example, for semi-dry concrete mixes used concrete containing 350 kg/m^3 of cement M500 and 70 kg/m^3 of ash. Concrete after 7 hours hardening in normal conditions (without thermal treatment) ripe 10 strength class. With heat treatment, at maximum temperature of 800 Co for the same period of time managed to achieve B25 strength class.Effect of ash on the early strength of concrete the heat treatment also depends on the reactivity of the cement at elevated temperatures.

In the manufacture of semi-dry concrete mixes on the basis of 3 different cements of the same type and strength class (42.5 M500) each time 25 % by weight replaced by fly ash. After 6-hour heat treatment at a temperature of 600 C samples-prisms were tested for compressive strength (table 5). The strength characteristics of the solutions were not identical. While the relative compressive strength of ash containing mixture 1 was 73,7 %, the same rate of mixture 2 was equal 81.3%.

The results of experimental laboratory studies conducted with the purpose of optimization of concrete mix for production of reinforced concrete structures with the use of ash is given in table 6.

Table 6: The results of laboratory experiments using ash

Name of concrete	Cement кg/м^3	Ash кg/м^3	w/c	Compressive strength MPa		
				20 hours	7 days	28 days
Concrete 1	410		0,48	28,8	52,4	62,9
Concrete 2	350	80	0,48	28,5	54,5	66,3
Concrete 3	370	80	0,48	26,6	52,4	63,3
Concrete 4	380	80	0,48	23,6	51,5	62,0

Despite the decrease in the content of cement (M500) at 60 kg/m^3 with the addition of ash in the amount of 80 kg/m^3, after 20 hours exposure in air at a temperature of 200C (a mixture of 1 - 28,8 MPa and a mixture of 2 - 28,5 MPa) managed to achieve the same compressive strength. After only 7 days (1 day of exposure in air and 6 days of aging in water at 200C) indicator of strength of the mixture with ash content was approximately 2 MPa higher than the control mixture (52,4 MPa to 54.5 MPa). After 28 days (final exposure in air at 200C) strength of control mix was lower than in the mixture with ash content more than 3 MPa (62,9 MPa and 66,3 MPa).

The use of ash as a mineral additive in the manufacture of concrete and reinforced concrete structures and products is an indispensable attribute of modern concrete technology. Along with «filler effect» ash, through «ball bearing effect», improves the workability and density of concrete mixes, with pozzolanic properties contributing to further enhance the strength and durability of hardened concrete. By adding optimum amounts of ash can be increased the strength of the formed fresh concrete from semi-dry concrete the strength of concrete in the production of reinforced concrete constructions and products.

By means of optimization ash containing concrete mixtures, it becomes possible to offer producers of concrete and reinforced concrete structures and products economical formulations of concrete. The use of ash leads to improved technical and economic characteristics of concrete and reinforced concrete structures and products.