Pergamon

Cement and Concrete Research, Vol. 25, No. 8, pp. 1610-1614, 1995

0008-8846/95 $9.50+.00

0008-8846(95)00155-7

UTILIZATION OF LIGNITE ASH IN CONCRETE MIXTURE

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(Communicated by F.W. Locher)
(Received July 13; in final form August 8, 1995)

ABSTRACT

In this article 11 ashes from various Turkish lignite sources were studied to show the effects upon lignite ash quality for use as a mineral admixture in concrete. The lignite ashes were classified into two general types (Class A and Class B) based on total of silica, alumina, and iron oxide. Total content of the three major oxides must be more than 50 % for Class A lignite ash and more than 70 % for Class B lignite ash. When 25 % of the cement was replaced by LA-1 (Class A) lignite ash, based on 300 kg/m^3 cementitious material, the 28-day compressive strength increased 24.3 % compared to the control mix. The optimal lignite ash replacement was 25 % at 300 kg/m^3 cementitious material.

Introduction

The growth of coal consumption in increased number of coal fired power plants and the resulting increase in production of solid waste creates serious problems for both power-generating industries and environmentalists(1,2). Power plant ash can be used as a filler material(3).

Coal ash might be used as a mineral admixture in portland cement concrete in the same way as classic puzzolonic materials, fly ash or blast-furnace slags(4,5,6). Specifications of cementing coal ash base primarily upon the combined silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3) and infer that these characteristics are directly associated with the coal origin, that is, the most convenient material, *especially lignite ash with high calcium oxide and/or magnesium oxide must be preferred.*

Mineral matter is generally to be the sum of all inorganic substances that are present in coal. Since coal ash is a complex mixture of many substances, it is difficult to explain the relationship between the chemical composition of the ash and its supplementary cementing material characteristics.

The hydration of cement is an exothermic reaction which liberates a considerable quantity of heat. Supplementary cementing material such as fly ash, slag, mineral admixtures, coal ash, and others are suitable for lowering the maximum temperature of mass concretes made with ordinary portland cement alone(7). The cementitious material presently used for that purpose as cement additives. Partly-refined chemical by-product gypsums were also used as cement additives instead of natural gypsum(6.9.10).

Since ash composition of different coals vary widely, the supplementary cementing characteristics also vary considerably and very little information is available on concrete containing higher percentages of coal ash. Consequently, there is in determining this effect since it can be used to advantage in improving the available design methods for concrete structure. Typical constituents of coal ash and the approximate limits of the fraction in which they occur in the ash of coals mined is shown in Table 1(10).

Such an ash would normally contain a variety of minerals, the relative proportions of which in the composition of the ash will depend on the particular coal which is to be utilized to form the ash.

In this work, the lignite ashes were classified into two general types based on total of silica, alumina, and iron oxide contents. The optimal cement replaced by lignite ash was identified. The objectives of this study is to investigate some of the relationships between the chemical and physical properties of lignite ashes and their reactivity with portland cement.

TABLE 1
Typical Costituents of Coal Ash and Their Approximate Limits, Weight Percent

Constituent	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	$Na_2O + K_2O$
Limits	30-60	10-40	3-30	1-20	0.5-4	0.5-3	1-3

Materials and Methods

Lignite samples used in this work supplied from Turkish lignite sources. Approximate analyses of these samples were performed according to ASTM Standards(11). All of the chemical analyses of the ash samples obtained from the lignites were carried out according to ASTM Standards. Ash content of the lignites were determined according to ASTM Standards(12) and the mineral matter contents of the ashes were determined by the ASTM Standards(13). Table 2 shows the approximate analysis results of the lignites. The analysis results of the air-dried ash samples are given in Table 3.

TABLE 2
Approximate Analyses of Lignite Samples, Weight Percent

Lignite Code	Moisture	Volatile Matter	Fixed Carbon	Ash
L-1	18.7	47.3	87.4	6.6
L-2	16.2	42.8	34.2	6.8
L-3	14.6	43.6	33.7	8.1
L-4	15.3	41.0	30.0	10.7
L-5	10.1	39.2	43.0	13.7
L-6	14.0	38.9	33.3	14.4
L-7	16.2	28.7	37.8	32.3
L-8	25.4	35.3	13.9	26.4
L-9	3.6	27.0	33.6	45.8
L-10	18.2	30.2	11.0	40.6
L-11	17.3	28.8	12.6	42.3

Cement test mixes were prepared according to Turkish Standards (TS 14). The physical tests were carried out according to TS 24. In all tests sample passing 45 μm (No : 325) sieve was used.

Results and Discussion

Appropriate chemical data for portland cement, trass, fly ash,(15,16,17,18) blast furnace slag(19,4) and lignite ash are shown in Table 4. The physical data for the lignite ash (LA-1) and portland cement mixes compared to the control mix are given in Table 5. The compressive strength test results for Class A and Class B lignite ashes and portland cement mixes are summarized in Table 6.

TABLE 3
Chemical Analyses of Lignite Ash Samples, Weight Percent

Lignite Code	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O+ K_2O	SO_3	$SiO_2 + Al_2O_3 + Fe_2O_3$
Class A								
LA-1	15.2	23.5	18.9	25.6	12.5	2.4	1.9	57.6
LA-2	15.3	24.4	20.4	24.4	13.3	0.7	1.5	60.1
LA-3	20.3	22.2	21.2	24.5	8.4	1.6	1.8	63.7
LA-4	22.8	20.4	21.9	21.6	9.5	1.8	2.0	65.1
Class B								
LA-5	22.5	24.2	25.0	24.1	2.1	1.5	0.6	71.7
LA-6	12.2	30.6	44.3	5.7	2.1	4.4	0.7	87.1
LA-7	16.4	38.3	34.8	6.7	1.3	2.0	0.5	89.5
LA-8	55.4	22.5	12.4	4.2	2.1	1.4	2.0	90.3
LA-9	60.2	17.8	14.2	1.3	4.4	1.3	0.8	92.2
LA-10	48.2	36.4	9.4	3.1	0.6	1.7	0.6	94.0
LA-11	54.7	29.2	11.5	1.2	1.0	1.8	0.5	95.4

Data for the chemical analyses of lignite ash samples from the present work as summarized in Table 3 shows that lignite ashes are classified into two general types : Class A and Class B. The specification bases this designation primarily upon the combined silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3). The three major oxides must be total more 70 % for Class B lignite ash.

From the data in Table 6, it can be shown that, based on 300 kg/m^3 cementitious material; when 25 % of the cement was replaced by Class A lignite ash (sample code : LA-1) the 28 day compressive strength increased by 24.3 % compared to the control mix. When 25 % of the cement was replaced by Class B lignite ash (sample code : LA-6) the 28-day compressive strength decreased by 4.4 % compared to the control, and when 25 % of the cement was replaced by another lignite ash (sample code : LA-11), the strength decreased by 16.4 % compared to the control. The results of these comparisons are summarized in Table 7.

From these results, it can be suggested that the cementing properties of lignite ashes has increased with the decreasing the percent of their three major oxides. Lignite ashes have the three major oxides more than 70 % can be rejected as cementing materials. However, they might be accepted as mineral admixtures in portland cement concrete. In an earlier article, the hydration and setting time of MgO-type expensive

TABLE 4
Chemical Composition of Portland Cement, Trass, Fly, Ash and Lignite Ash, Weight Percent

Constituent	Portland Cement	Trass	Fly Ash		Blast Furnace Slag		Lignite Ash	
			min	max	min	max	min	max
SiO_2	20.9	61.0	32	64	35	53	12	61
Al_2O_3	5.9	17.6	17	27	9	23	17	39
Fe_2O_3	4.5	5.8	3	15	1	20	8	45
CaO	63.1	7.1	2	25	5	40	1	26
MgO	1.6	1.7	1	8	1.5	10	0.3	14
K_2O	0.9	0.6	0.1	0.6	0.2	3.5	0.2	10
Na_2O	0.2	0.2	0.2	1.4	0.2	2.0	0.1	3.5
SO_3	1.3	0.2	0.2	0.6	0.4	3.0	0.4	2.5
Loss on Ignition	1.6	5.8	0.1	0.7	0.4	3.5	0.1	0.6

TABLE 5
Physical Data for the Lignite Ash (LA-1) and Portland Cement Mixes

Portland Cement kg/m^3 a	Lignite Ash (LA-1) kg/m^3	Natural Sand kg/m^3	Crush Stone kg/m^3	Water kg/m^3	Compressive Strength b, N/mm^2				
					1 Day	7 Day	28 Day	56 Day	90 Day
300	0	700	1000	170	11.2	26.8	34.1	37.0	39.5
300	50	700	1000	170	10.8	27.6	37.8	38.3	40.6
300	66	700	1000	170	10.5	29.3	40.2	44.8	47.8
300	85	700	1000	170	9.4	29.0	41.0	45.6	48.2
300	104	700	1000	170	8.1	28.8	42.1	46.7	49.7
300	120	700	1000	170	5.2	29.6	44.7	47.8	50.6
300	180	700	1000	170	3.8	30.4	46.6	49.9	52.3

a To obtain cementitious material, add cement + lignite ash (LA-1)
b Based on 5 % air content

TABLE 6
Physical Data for the Lignite Ashes and Portland Cement Mixes

Sample Identity	Portland Cement kg/m^3	Lignite Ash kg/m^3	Compressive Strength, N/mm^2				
			1 day	7 Day	28 Day	56 Day	90 Day
Control mix	300	0	11.2	26.8	34.1	37.1	39.5
Class A							
LA-1	225	75	8.8	29.0	42.4	45.3	47.6
LA-2	225	75	8.6	28.8	39.2	43.8	46.2
LA-3	225	75	8.2	28.2	38.3	42.1	45.2
LA-4	225	75	7.8	27.3	36.1	40.4	44.3
Class B							
LA-5	225	75	7.4	27.0	32.6	38.2	39.0
LA-6	225	75	6.4	26.2	30.0	37.0	38.6
LA-7	225	75	6.0	26.0	29.6	36.4	38.5
LA-8	225	75	5.8	25.7	29.4	36.3	37.6
LA-9	225	75	5.7	25.4	29.0	36.6	37.6
LA-10	225	75	5.8	25.0	28.8	36.0	37.5
LA-11	225	75	5.6	24.6	28.5	36.2	37.0

Aggregates: Natural Sand : 700 kg/m^3, Crash Stone : 1000 kg/m^3, Water : 170 kg/m^3

TABLE 7
Increases and Decreases of Compressive Strenghts in LA Mixes Compared to the Control Mix

Class A	Increases in Compressive Strenght	Class B	Decreases in Compressive Strenght
LA-1	24.3	LA-5	4.4
LA-2	15.0	LA-6	12.0
LA-3	12.3	LA-7	13.2
LA-4	5.9	LA-8	13.8
		LA-9	15.0
		LA-10	15.5
		LA-11	16.4

cement was investigated[20] and suggested that the setting time (the initial and final) of the cement is increased with increasing of MgO contents. It shows that the addition of MgO retards the initial hydration of cements and

increases the setting time. MgO contents of Class A type lignite ashes, especially LA-1 and LA-2, used in the present work are also higher than those of Class B types. The effects of MgO on the properties of cement were investigated in another paper[21] and the effects of MgO on the initial hydration and setting time of cement were discussed in detail. Many factors can influence hydration and setting time of cement, and the influences of various chemical admixtures, fly ashes, blast furnace slag, and silica fumes, etc. have been comprehensively studied[22,23,24].

CONCLUSION

The results demonstrate that the optimal Class A lignite ash (sample code : LA-1) replacement to achieve optimal 28-day compressive strengths. Class A lignite ash vary in their degree of reactivity with cement despite similar chemical composition compared to similar concretes such as fly ash concrete and blast furnace slag concrete. The construction industry is keenly interested in replacing a large part of cement with beneficial lignite ash in concrete because of the economy that can be achieved.

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