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STABILIZATION OF FLY ASH WITH CEMENT

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Abstract

The principal idea lying beneath the effort presented herein is that beneficial assets of the one type of ash could compensate for the shortcomings of the other. Compressive strength development, pozzolanic activity potential and nature of hydration products of all ternary cements were closely monitored and presented in comparison to the respective properties of the initial binary blends. Moreover, efficiency factors were calculated for all new systems and were further used to validate previously reported expressions describing Binary Fly ash-Cement (BFC) systems. Results obtained indicate that previously developed analytical expressions, correlating active silica of SCMs and k-values, can be applied in the case of multicomponent ash systems as well.

Introduction

Fly Ash is a by-product of the combustion of pulverized coal in thermal power plants. It is removed by the dust collection system as a fine particulate residue from the combustion gases before they are discharges into the atmosphere. Fly Ash particles are typically spherical, ranging in diameter from less than 1 micron to 150 micron, the majority being less than 45 micron. The range of particle sizes in any given fly ash is largely determined by the type of dust collection equipment used. The fly ash from boilers at some older plants, where mechanical collectors alone are employed, is coarser than from plants using electrostatic precipitators.

The chemical composition of fly ash is determined by the types and relative amounts of incombustible matter in the coal used. More than 85% of most fly ashes comprise chemical compounds and glasses formed from the elements of silicon, aluminium, iron, calcium and magnesium. Generally, fly ash from the combustion of sub-bituminous coals contains more calcium and less iron than fly ash from bituminous coal.

Unburnt coal gets collected with the fly ash as carbon particles, the amount being determined by such factor as the rate of combustion, air fuel ratio, and degree of pulverization of the coal. In general, thermal stations that operate only intermittently (peak load stations), burning bituminous coals, produce the largest percentage of unburnt carbon in the fly ash.Fly ashes exhibit pozzolanic activity. A pozzolan is define “as a siliceous and aluminous material which in itself possesses little or no cementoius value but which will, in finely divided form and in the presence of moisture, cjhemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementious properties”. Fly ashes contain meta-stable alumino-silicates that will react with calcium ions, in the presence of moisture, to form calcium silicate hydrate.Over 2000 years ago, Roman builders recognized that certain volcanic ashes were capable of combining with lime to form effectively cements. This pozzolanic property was widely exploited in ancient construction, and many structures built during the roman period can still be seen today.

The properties of both freshly mixed and hardened concretes are intimately and complexly associated with the characteristics and relative proportions of the material used in their manufacture. In fresh concrete, the coarse and fine aggregates are suspended in cement paste. The consistency of the mass is controlled by the fluidity of the paste and the quantity and grading of the aggregate. In hardened concrete, the properties such as strength are functions of the density of the paste, which is controlled by the ratio of water to cement in the original mixture. If the aggregates are of satisfactory quality, the performance of concrete in sevice is primarily influenced by the properties of hardened paste. For a Portland cement of given composition, the strength and porosity of the hydrated mass are dependent almost entirely upon the water-to-cement ratio. The lower the ratio, the greater is the strength and the water-tightness. Durability in service, or resistance to weathering and attack by aggressive environments, is a function of both strength and water-tightness.

The inclusion of fly ash in concrete affects all aspects of concrete properties. As a part of the composite that forms the concrete mass, fly ash acts in part as fine aggregate and in part as a cementitious component. It influences the rheological properties of the fresh concrete, the strength, finish, porosity, and durability of the hardened mass, and the cost and energy consumed in manufacturing the final product.

Fig 1: Compaction of fly ash with cement

Literature Review

S.K. Antiohos, V.G. Papadakis:

For overcoming certain drawbacks characterizing both basic types of fly ash (of high and low calcium content), different ash intermixtures consisting of two types of fly ashes were prepared. The principal idea lying beneath the effort presented herein is that beneficial assets of the one type of ash could compensate for the shortcomings of the other. Compressive strength development, pozzolanic activity potential and nature of hydration products of all ternary cements were closely monitored and presented in comparison to the respective properties of the intial binary blends. Moreover, efficiency factors were calculated for all new systems and were further used to validate previously reported expression describing binary fly ash-cement systems. In accordance with previous works, ternary fly ash system examined here outperformed the respective binary system almost throughout the curing period. Synergy between the different types of fly ashes were considered the main reason for the excellent performance of the ternary mixtures. Result obtained indicate that previously developed analytical expressions, correlating active silica of SCM and k-values, can be applied in the case of multicomponent ash system as well.

N. Bouzoubaa, M. Zhang:

The effects of grinding fly ashes on their physical and chemical properties, and their effect on the properties of mortars and concretes incorporating the blended fly ash cements, are discussed. The production of blended fly ash cements produced by grinding portland cement clinker and fly ash together versus separate grinding of the materials followed by blending is described. The combined grinding of the portland cement clinker, fly ash, gypsum, and a superplasticizer to produce a blended cement is discussed, and reference is made to the optimum grinding processes and the production of high-volume fly ash blended cements. The paper concludes with a list of recommendations for needed research.

S. Tsimas:

For comparing the relative performance of various supplementary cementing materials (SCMs: silica fume, fly ash, slag, natural pozzolans, etc.) as regards Portland cement, the practical concept of an efficiency factor may be applied. The efficiency factor (or k value) is defined as the part of the SCM in an SCM-concrete that can be considered as equivalent to Portland cement. In the present work, an alternative procedure for experimental determination of the k value is proposed, using the concept of the pozzolanic activity index. For the first time, also, the k value for equivalent strength was correlated with the active silica content of the SCM through analytical expressions. Artificial pozzolanic materials of various compositions and some natural pozzolans were studied. It was found and verified by experimental comparison that these expressions are valid only for artificial SCMs (fly ash, slag), whereas in the case of natural SCMs the k value is overestimated. Thus, knowing primarily the active silica content of the SCM, a first approximation of the k value can be obtained and, further, the strength of a concrete incorporating artificial SCM can be predicted.

Katarzyn Synoweic

Two types of fly ash were used – siliceous (V) and calcareous (W). The influence of fly ash type on properties of mortars was evaluated on the base of results of following tests: compressive strength, consistency and its stability in time and chloride ions permeability and carbonation depth. It was claimed that mortars made with cements containing calcareous fly ash (W) are characterized by higher compressive strength (at each age). Moreover, negative impact of calcareous fly ash (W) on rheological properties of mortars was observed. Durability tests revealed favourable effect of calcareous fly ash on resistance of mortars to corrosive agents attack – lower chloride ions permeability and carbonation depth in comparison to siliceous fly ash – slag cement mortars.

K. Maganari:

Evaluating the performance of ternary blended cements, incorporating mixtures of two different types of fly ash (of high and low calcium content).The main target of this study was to investigate whether and by what means, the introduction of a certain type of fly ash into a fly ash-cement matrix containing a different type of ash, can improve the performance of the initial binary system. For achieving this, new pozzolans were prepared by mixing, in selected proportions, a high lime fly ash with an ash of lower calcium content. The efficiency of the new materials was examined in terms of active silica content, pozzolanic activity potential, strength development, k-values and progress of the pozzolanic action by means of fixed lime capabilities. The results obtained demonstrated that the mixture containing equal amounts of each fly ash were the most effective for moderate cement substitution, whilst for higher replacements the intermixtures possessing the highest active silica content shows supremacy at almost all hydration ages. The superior performance of the ternary fly ash blends was mainly attributed to synergistic effects detected for all the ashes utilized. These were quantified in each case and almost linear correlations were obtained with the k-values of the most efficient ternary mixes.

Dr S L Patil, S Suman:

Fly ash, a waste generated by thermal power plants is as such a big environmental concern. The investigation reported in this paper is carried out to study the utilization of fly ash in cement concrete as a partial replacement of cement as well as an additive so as to provide an environmentally consistent way of its disposal and reuse. This work is a case study for Deep Nagar thermal power plant of Jalgaon District in MS. The cement in concrete matrix is replaced from 5% to 25% by step in steps of 5%. It is observed that replacement of cement in any proportion lowers the compressive strength of concrete as well as delays its hardening. fly ash-cement matrix containing a different type of ash, can improve the performance of the initial binary system. For achieving this, new pozzolans were prepared by mixing, in selected proportions, a high lime fly ash with an ash of lower calcium content. The efficiency of the new materials was examined in terms of active silica content, pozzolanic activity potential, strength development, k-values and progress of the pozzolanic action by means of fixed lime capabilities. The results obtained demonstrated that the mixture containing equal amounts of each fly ash were the most effective for moderate cement substitution, whilst for higher replacements the intermixtures possessing the highest active silica content shows supremacy at almost all hydration ages. The superior performance of the ternary fly ash blends was mainly attributed to synergistic effects detected for all the ashes utilized. These were quantified in each case and almost linear correlations were obtained with the k-values of the most efficient ternary mixes.

III. Definitions

Cement stabilization is done by mixing pulverized soil and Portland cement with water and compacting the mix to attain a strong material. The material obtained by mixing of material and cement is known as slurry of cement. The slurry of a cement becomes a hard and durable structural material as the cement hydrates and develops strength.

Cement stabilization is done while the compaction process is continuing. During the compaction process we use some amount of cement. Some void space can be found in particle. Cement is just like paw, so cement can fill the void space of particle easily. As a result, void ratio of particle may reduce. After this primary tasks,when we add water in the compaction the cement reacts with water and become hard. So unit weight of material is also may increased. Because of the hardening of cement, shear strength and bearing capacity will be increased. Because of the stabilization, permeability of any material may decrease.

Fig 2: Material Used

3.1. FACTORS AFFECTING CEMENT STABILIZATION

- Quantity of cement: A large amount of cement is needed for cement stabilization.
- Quantity of water: Adequate water is needed for the stabilization.
- Mixing, compaction and curing: Adequate mixing, compaction and curing is needed for cement stabilization.

3.2. ADVANTAGES OF CEMENT STABILIZATION

- It is widely available.
- Cost is relatively low.
- It is highly durable.
- Soil cement is quite weather resistant and strong.
- Cement stabilization as it requires least amount of cement.
- Cement reduces the swelling characteristics of any material.

3.3. DISADVANTAGES OF CEMENT STABILIZATION

- Cracks may form in soil cement.
- It is harmful for environment.
- It requires extra labour.

The quantity of water must be sufficient for hydration of cement and making the mixture workable.

IV Methodology

The experimental work consists of the following steps:

a) Specific Gravity of fly ash
b) Particle size distribution of fly ash by sieve analysis
c) Determination of the maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by Proctor compaction test
d) Permeability of fly ash
e) Determination of compressive strength of fly ash with cement

a) Specific Gravity of fly ash

Specific Gravity of is the ration of the density of a substance to the density of a reference substance; equivalently, it is the ratio of the mass of a substance to the mass of a reference substance for the same given volume. Apparent specific gravity is the ratio of the weight of a volume of the substance to the weight of an equal volume of the reference substance. The reference substance for liquids is nearly always water at its densest (at 4ºc or 39.2º F); for gases it is air at room temperature (20ºc or 68º F). Nonetheless, the temperature and pressure must be specified for both the sample and the reference. Pressure is nearly always 1 atm (101.325 kpa).

Temperature for both sample and reference vary from industry to industry. In british beer brewing, the practice for specific gravity as specified above is to multiply it by 1000. Specific gravity is commonly used in industry as a simple means of obtaining information about the concentration of solutions of various materials such as brines, hydrocarbons, antifreeze coolants, sugar solutions (syrups, juices, honeys, brewers wort, must, etc.) and acids.

Fig 3: showing density bottle method apparatus used for determining Specific gravity

b) Particle Size Distribution

The results from sieve analysis of the fly ash when plotted on a semi-log graph with particle diameter or the sieve size as the abscissa with logarithmic axis and the percentage passing as the ordinate gives a clear idea about the particle size distribution. From the help of this curve, D10 and D60 are determined. This D10 is the diameter of the soil below which 10% of the soil particles lie. The ratio of, D10 and D60 gives the uniformity coefficient (Cu) which in turn is a measure of the particle size range.

Fly ash at any place is composed of particles of a variety of sizes and shapes, sizes ranging from a few microns to a few centimetres are present sometimes in the same sample. The distribution of particles of different sizes determines many physical properties of the soil such as its strength, permeability, density etc. Particle size distribution is found out by two methods, first is sieve analysis which is done for coarse grained soils only and the other method is sedimentation analysis used for fine grained soil sample. Both are followed by plotting the results on a semi-log graph. The percentage finer N as the ordinate and the particle diameter i.e. sieve size as the abscissa on a logarithmic scale. The curve generated from the result gives us an idea of the type and gradation of the fly ash.

Procedure to determine Particle Size Distribution Of fly ash

- For fly ash samples of fly ash retained on 75 micron I.S sieve.
- The proportion of fly ash sample retained on 75 micron I.S sieve is weighed and recorded weight of fly ash sample is as per I.S 2720.
- I.S sieves are selected and arranged in the order as shown in the table.
- The fly ash sample is separated into various fractions by sieving through above sieves placed in the above mentioned order.
- The weight of fly ash retained on each sieve is recorded.
- The moisture content of fly ash if above 5% it is to be measured and recorded.
- No particle of fly ash sample shall be pushed through the sieves.

Fig 4: showing sieves used for sieve analysis test

c) Proctor Compaction test

The proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given fly ash type will become most dense and achieve its maximum dry density. The test is named in honor of Ralph R Proctor, who in 1933 showed that the dry density of a fly ash for a given compaction effort depends on the amount of water the fly ash contains during fly ash compaction. His original test is most commonly referred to as the standard proctor compaction test; his test was later updated to create the modified proctor compaction test.

These laboratory tests generally consist of compacting fly ash at known moisture content into a cylindrical mold of standard dimensions using a compactive effort of controlled magnitude. The fly ash is usually compaction into the mold to a certain amount of equal layers, each receiving a number of blows from a standard weighted hammer at a specified height. This process is then repeated for various moisture contents and the dry densities are determined for each. The graphical relationship of the dry density to moisture content is then plotted to establish the compaction curve. The maximum dry density is finally obtained from the peak point of the compaction curve and its corresponding moisture content, also known as the optimal moisture content.

d) Permeability of Fly ash

Permeability is the property of rocks that is an indication of the ability for fluids (gas or liquid) to flow through rocks. High permeability will allow fluids to move rapidly through rocks. Permeability is affected by the pressure in a rock. The unit of measure is called the darcy, named after Henry Darcy. Sandstones may vary in permeability from less than one to over 50,000 millidarcys. Permeabilities are more commonly in the range of tens to hundreds of millidarciees. A rock with 25% porosity and a permeability of 1md will not yield a significant flow of water. Such “tight” rocks are usually artificially stimulated (fractured or acidized) to create permeability and yield a flow.

Fig 5: showing permeability test apparatus

e) Compressive Strength of Fly Ash with cement

Compressive strength is the capacity of a material to with stands loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate. In other words, compressive strength resists compression (being pushed together), whereas tensile strength resists tension (being pulled apart). In the study of strength of materials, tensile strength, compressive strength, and shear strength can be analyzed independently. Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures. Compressive strength is often measured on a universal testing machine; these range from vary small table-top systems to ones with over 53MN capacity.

V Result Discussion and Analysis

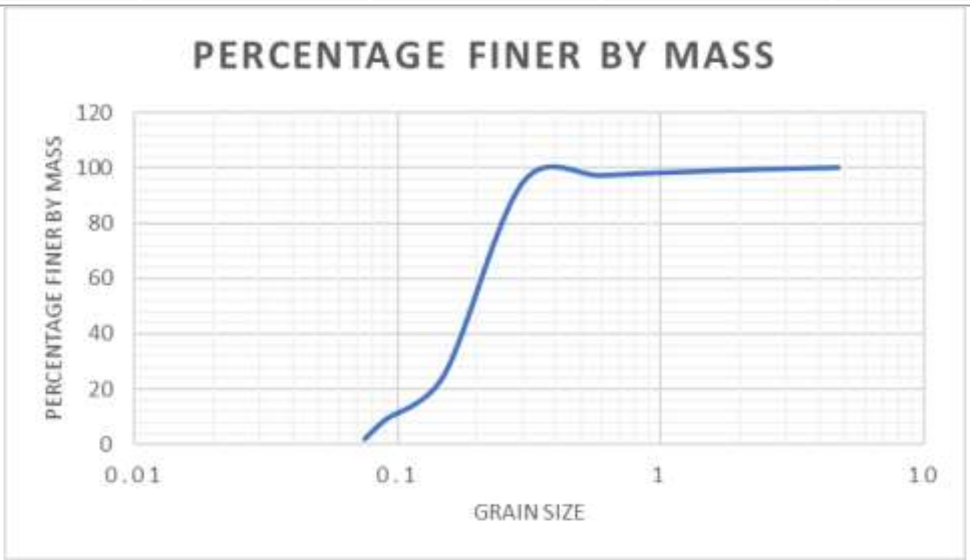
a) Specific Gravity:

S. No.	Observation Number	1	2	3
1	Weight of density bottle (W1 g)	31.72	31.80	31.83
2	Weight of density bottle + dry fly ash (W2 g)	46.60	46.92	46.83
3	Weight of bottle + dry fly ash + water at temperature T x0 C (W3 g)	91.07	91.08	90.96
4	Weight of bottle + water (W4 g) at temperature Tx0 C	82.24	82.23	82.25
	Specific gravity G at Tx0 C	2.459	2.411	2.384
	Average specific gravity at Tx0 C		2.418	

Table 1

b) Particle Size Distribution of Fly Ash

I.S sieve number or size in mm	Wt. Retained in each sieve (gm)	Cumulative weight retained on each sieve	Cumulative %age retained on each sieve	% finer
4.75	0	0	0	100
2.36	3	3	0.6	99.4
1.18	5	8	1.6	98.4
0.6	6	14	2.8	97.2
0.3	12	26	5.2	94.8
0.15	349	375	75	25
0.09	80	455	91	9
0.075	35	490	98	2
pan	10	500	100	2

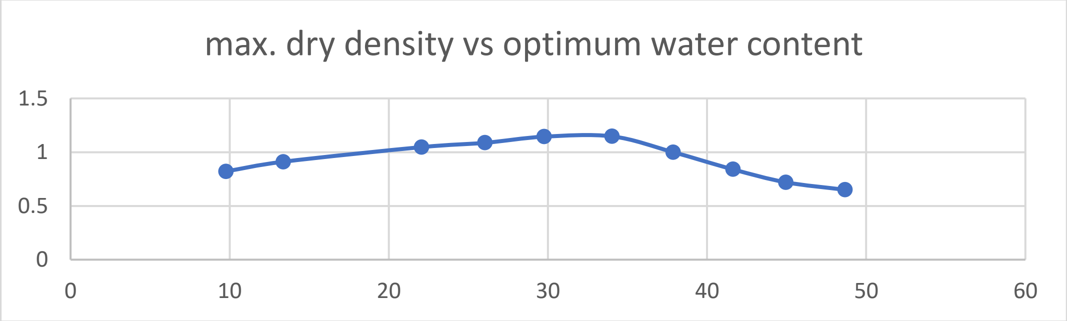


Graph 1

c) STANDARD PROCTOR COMPACTION TEST

Wt. of mould with fly ash	Wt. of compacted material	Wet density	W1	W2	After oven-drying	Wt. of water	Wt. of dry material	Water content (%)	Dry density
6620	902	0.902	12.77	25.25	24.14	1.11	11.37	09.76	0.821
6751	1033	1.033	13.56	25.17	23.80	1.37	10.24	13.37	0.911
6776	1058	1.058	14.39	30.30	27.92	2.38	13.53	17.59	0.900
6874	1156	1.156	12.74	22.81	20.99	1.82	08.25	22.06	0.947
7040	1322	1.322	14.18	27.44	24.70	2.74	10.52	26.04	1.049
7133	1415	1.415	12.32	26.71	23.41	3.30	11.09	29.75	1.090
7255	1537	1.537	14.40	24.60	22.01	2.59	07.61	34.03	1.147
7307	1589	1.589	14.27	28.03	24.25	3.78	09.98	37.87	0.840
7420	1702	1.702	13.31	34.54	28.30	6.24	14.99	41.62	1.231
7344	1626	1.626	13.16	35.27	28.38	6.84	15.22	44.94	1.122
7235	1517	1.517	13.18	37.62	29.66	8.02	16.48	48.66	1.030

TABLE 3



d) PERMEABILITY OF FLY ASH

H-U (cm)	H-L (cm)	ΔT (min)	K (cm/sec)
8.9	9.4	2	0.000361
9.4	9.9	2	0.000342
9.9	10.4	2	0.000325
10.4	11.0	2	0.000370
11.0	11.4	2	0.000236
11.4	12.0	2	0.000339
12.0	12.5	2	0.000269
12.5	13.1	2	0.000309
13.5	14.0	2	0.000240

Table 4

e) COMPRESSIVE STRENGTH OF FLY ASH WITH CEMENT AFTER 7 DAYS

FOR 5% FLY ASH

Sample number	Peak load	Peak compressive strength
1	92.9	18.58
2	47	9.41
3	56.3	11.27

FOR 8% FLY ASH

Sample number	Peak load	Peak compressive strength
1	1343	26.87
2	140.3	28.06
3	156.4	31.29

FOR 10% FLY ASH

Sample number	Peak load	Peak compressive strength
1	171.9	34.40
2	162.9	32.58
3	165.2	33.05

AFTER 14 DAYS

FOR 5% FLY ASH

Sample number	Peak load	Peak compressive strength
1	207.4	41.50
2	96.5	19.31
3	158.8	31.76

FOR 8% FLY ASH

Sample number	Peak load	Peak compressive strength
1	128	25.60
2	250.6	50.13
3	159.8	31.97

FOR 10% FLY ASH

Sample number	Peak load	Peak compressive strength
1	170.6	34.14
2	133	26.60
3	131.9	26.38

AFTER 28 DAYS

FOR 5% FLY ASH

Sample number	Peak load	Peak compressive strength
1	80	17
2	40	8
3	46	10

FOR 8% FLY ASH

Sample number	Peak load	Peak compressive strength
1	120.0	20
2	130.5	25
3	145.2	26

FOR 10% FLY ASH

Sample number	Peak load	Peak compressive strength
1	160	25
2	152.5	22
3	145.5	21

Table 5

V Conclusion

On the basis of present experimental study, the following conclusions are drawn:

- From above test we conclude that when we add 5% fly ash with cement then we get compressive strength 13.08 N/mm² in 7 days and 14 days we get 30.85 N/mm² , this means strength is increased with increase in setting time of cement.
- When we add 8% fly ash with cement we get strength in 7 days is 28.74 N /mm² and 14 days we get 35.9 N/mm². It means strength is increase.
- When we add 10% fly ash with cement we get strength in 7 days 33.34 N/mm² and 14 days we get 29.4 N/mm². It means strength decreases, we means that an adding more % of fly ash with cement strength is decrease with increased in time.

References

1. N. Bouzoubaa, M. Zhang, V.M. Malhotra, M.D. Golden, “Blended fly ash cements”a review, ACI Mater. J. 96 (6) (1999) 641–650.
2. R.V. Ranganath, R.C. Sharma, S. Krishnammorthy, “Influence of fineness and soluble silica of fly ashes on their strength development with respect to age” in: V.M. Malhotra (Ed.), Proceedings of the 5th CANMET/ACI International Conference on Fly ash, Silica Fume, Slag and Natural Pozzolans in Concrete, Milwaukee, US, vol. 1, 1995, pp. 1–20.
3. R.T. Hemmings, E.E. Berry, “On the glass in coal fly ashes: recent advances” Presented at the MRS Symposium, Pittsburgh, United States, vol. 113, 1988, p. 3.
4. S. Antiohos, V.G. Papadakis, K. Maganari, S. Tsimas, “The development of blended supplementary cementing materials consisting of high and low calcium fly ashes” Proceedings of the 11th International Congress on the Chemistry of Cement, Durban, South Africa, vol. 2, 2003, pp. 747–757.
5. S. Antiohos, S. Tsimas, “Investigating the role of reactive silica in the hydration mechanisms of high-calcium fly ash/cement systems” Cem. Concr. Compos. 27 (2) (2004) 171–181.
6. T.R. Naik, S. Singh, B. Ramme, “Mechanical properties and durability of concrete made with blended fly ash” ACI Mater. J., 95 (4) (1998) 454–462.
7. T.R. Naik, S. Singh, M.M. Hossain, “Enhancement in mechanical properties of concrete due to blended ash” Cem. Concr. Res. 26 (1) (1996) 49–54.
8. S. Antiohos, K. Maganari, S. Tsimas, “Evaluation of ternary fly ash intermixtures for use as supplementary cementing materials” Cem. Concr. Compos. 27 (3) (2005) 349–356.
9. 9.V.G. Papadakis, S. Antiohos, S. Tsimas, “Supplementary cementing materials in concrete — part II: a fundamental estimation of the efficiency factor” Cem. Concr. Res. 32 (10) (2002) 1533–1538.