Physical and Mechanical Properties of Fly Ash of Kosova B TPP for Utilization as Product for Partial Cement

Mevlan Qafleshi[1], Driton R. Kryeziu[2], Misin Misini[3], Lulezime Aliko[4]

[1] *Faculty of Mathematical Engineering and Physical Engineering, Polytechnic University of Tirana, Tirana, Albania*
[2] *University for Business and Technology, Prishtina, Republic of Kosovo*
[3] *Faculty of Civil Engineering and Architecture, University of Prishtina, Prishtina, Republic of Kosovo*
[4] *Faculty of Mathematical Engineering and Physical Engineering, Polytechnic University of Tirana, Tirana, Albania*

ABSTRACT: *In Kosovo the electricity generation from lignite-fired power plants produces around 1 Mt/annually of fly ash as combustion byproduct. The energy demand in Kosovo increases each year and the same with the lignite consumption that directly leads to the increase of fly ash production. Since the first operation of first thermal power plant till now there are around 27 Mt of unutilized fly ash, i.e. fly ash in Kosovo has not been treated or utilized at all. In the other hand, the concrete industry, respectively cement production process is associated with CO_2 emission, around 5% of world's CO_2, which is a greenhouse gas. The cement production is increasing due to high market needs and consequently more CO_2 emission in the atmosphere. The results of studies and researches show that each tonne of cement contributes with the emission of around 1 tonnne of CO_2. In this paper, the studying of physical and mechanical properties of Kosovo B TPP Fly ash intends to boost efforts for utilization of fly ash of Kosovo as partial cement replacement or admixture through its standardization as construction product. The benefits of this utilization will be of great importance for saving the environment, the improvements of many properties of concrete built with a certain percentage of fly ash, and finally with the direct substitution of cement with fly ash which results with the decrease of CO_2 emissions from cement industry. The test results of this study are in favor of these benefits.*

Keywords: *Kosovo, fly ash, compressive strength, flexural strength, initial setting, standardization.*

I. INTRODUCTION

The fly ash produced in Kosova A and Kosova B thermal power plants has high lime content, i.e. it is calcareous fly ash possessing cementitious and hydraulic properties [1]. As according to the ASTM C618 12a, the general classification of Fly ash is done conform to the percentage content of CaO, and since the Kosovo fly ash is produced from burning lignite, the test analyses showed that lime content in fly ash was 32.92 % [2]. The testing has been done in accordance with SIST EN 197-1, clause 3.1 and this percentage value classifies the Kosova B TPP Fly ash to Class C [3] [4]. Class C Fly ash in addition of pozzolanic properties has also cementitious properties enabling the use of this ash in cement, respectively concrete industry.

The chemical analyses regarding the composition of the fly ash from Kosova B TPP show no different or exceptional properties comparing to the fly ashes from other countries. This similarity in chemical composition would pave the way for utilization of Kosovo fly ash in the cement and concrete industry. As the chemical composition of fly ash generally allows its use, then the physical and mechanical properties should be in accordance with the standards that depict the use of fly ash in industry. This paper study aims to examine and test the basic physical and mechanical properties of the Kosovo fly ash and standardize it as an industrial construction product. This utilization may have a fundamental importance for producing green concrete: less CO2 emissions and less surface land pollutions.

II. FLY ASH PRODUCTION FROM LIGNITE COMBUSTION

According to European standard for Fly ash in Concrete, fly ash is defined as "Fine powder of manly spherical, glassy particles derived from burning of pulverized coal, with or without co-combustion materials, which has pozzolanic properties and consists essentially of SiO_2 and Al_2O_3 [5].

Kosovo with lignite reserves around 14 Bt [6] has oriented its energy strategy towards the Thermal Power plants with lignite as burning fuel. The total installed power capacity of TPP Kosova A and B is 1478 MW. The energy generation only from Kosovo Energy Corporation TPPs is over 97%. The rest is from hydro-power-plants [7]. The Kosovo Government has planned the construction of one other TPP unit "The New Kosovo", with anticipated installed capacity 1000 MW in the first phase, and with another 1000 MW in the second phase [8]. The increase of generating capacities implies increase of lignite consumption, more fly ash consequently.

Table I: Kosovo lignite quality and parameters [9]

Ash content	**12-21%. The average values 14-17%**		
Moisture content	**35-50%**		
Heating values	**Bardh -Mirash**	**7800 KJ/kg**	
	Sibovc	**8100 KJ/kg**	
	Total reserves	**29%**	**> 8.4 MJ/kg**
		43%	**7.7-8.4 MJ/kg**
		25%	**5.8-7.7 MJ/kg**
Sulfur content	**1 %. In all deposits/mines. The average content of combustible sulfur is 0.35%**		
Lime	**The concentration of lime is sufficient to absorb the SO_x gas emitted during combustion- no need for desulfurization of flue gases**		

From the analyses of Kosovo lignite, the content of ash in lignite is around 14-17% by mass [9]. This indicates that from burning of 1ton lignite the residue ash is around 160 kg, 80% of which is captured by ESP as Fly ash [10]. A calculation shows that up to 2012, in Kosovo there are around 27 Mt of unutilized fly ash. Only in 2012 the lignite combustion in Kosova A and B TPP produced around 1 Mt of fly ash [4]. Taking an average of 16% of ash content in Kosovo lignite, it the Table I it is shown the quantity of fly ash production during 2002-2012.

Table II: Fly ash production in TPP Kosova A and Kosova B [11] [12]

	Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Lignite consumption	Mt	5.23	5.64	5.59	6.27	6.35	7.11	7.46	8.41	9.34	9.11	9.35
Ash production	Mt	0.84	0.90	0.89	1.00	1.02	1.14	1.19	1.35	1.49	1.46	1.50
Fly ash production	Mt	0.67	0.72	0.72	0.80	0.81	0.91	0.95	1.08	1.20	1.17	1.20

As it s shown, the residues of burning lignite are millions of tonnes of fly ash that up to now in Kosovo have not been utilized at all. Explicitly said this ash is a waste. As many countries in the world utilize Fly ash either as direct cement replacement in concrete production and/or as mineral additive in concrete for improving specific properties of mortars and concrete, in Kosovo the Fly ash utilization is not taking place.

The use of fly ash in concrete industry has manifold advantages, apart from those environmental [13]. A brief description includes the improved workability and consistency of concrete made with fly ash, reduction of water demand [14], concrete pumping, compatibility, flow ability, reduced agglomeration, less risk of surface shrink holes [14], reduces water segregation [15].

The crucial part of this study focuses on the physical and mechanical properties of Kosovo Fly ash with the aim of standardizing this waste residue to a product conform to European Standard EN 450-1 for use in construction industry [5]. The results of this standardization would avoid all suspicions and concerns for the utilizations of Fly ash from KEK TPPs in concrete industry. If not to the world, but in Kosovo this would be a milestone of a great importance, economically and environmentally.

III. CHEMICAL AND MINERALOGICAL COMPOSITION OF KOSOVO B FLY ASH

The chemical composition favors to a great extent the utilization of fly ash in concrete industry as partial cement replacement. Based on its chemical composition, or better said due to high CaO content (in % by mass), Kosova B Fly ash belongs to calcareous fly ash, i.e. Class C fly ash [4].

Table III: Chemical composition of Kosovo B fly ash

constituent	formula	%/wght
Silica	SiO_2	29.7
Alumina	Al_2O_3	10.65
Iron Oxide	Fe_2O_3	6.18
Lime	CaO	32.92
Magnesium oxide	MgO	5.93
Sulfur	SO_3	9.98
Sodium oxide	Na_2O	0.74
Potassium oxide	K_2O	0.61
Loss on ignition		2.09

These chemical constituents influence the properties of concrete produced with a certain percentage of fly ash as cement replacement or admixture.

IV. PHYSICAL AND MECHANICAL PROPERTIES OF FLY ASH OF KOSOVO B TPP

The ash samples for analyses of physical and mechanical properties were taken from Kosovo B TPP and physical and mechanical analyses were conducted at laboratory **ZAG, Department of materials, Laboratory for cement, mortar and ceramics, Ljubljana, Slovenia**. The analyses were conducted in conformity with European Standards SIST EN 450-1:2005 5.2 and 5.3 [5].

Table IV: Physical properties of Fly ash

Component	Measured	Requirements SIST EN 450-1, cl. 5.3	Test method
Bulk density	**2.56 g/cm^3**	**-**	**SIST EN 196-6**
Fineness	**35.9 %**	**□ 40%, N category**	**SIST EN 451-2**
Soundness (expansion) CEM I +EF	**1.1 mm**	**□10 mm**	**SIST EN 450-1, cl. 5.3.3**
Water for standard consistency: **CEM I** **CEMI+ EF**	 **30.0%** **31.8 %**	 **-** **-**	**SIST EN 450-1, cl. 5.3.5**
Initial setting **CEMI I** **CEM I + EF**	 **185 min** **260 min**	 **□ 370 min**	**SIST EN 450-1, cl. 5.3.5**
Final setting **CEM I** **CEM I +EF**	 **230** **290**	 **-** **-**	**SIST EN 450-1, cl. 5.3.5**
Activity index in 28 days	**79.5 %**	**□ 75%**	**SIST EN 450-, cl. 5.3.2**
Activity index in 90 days	**87.1 %**	**□ 85 %**	**SIST EN 450-, cl. 5.3.2**

4.1. Soundness 1.1 mm

According to Brown et al. "Soundness is the ability of a cement paste, mortar or concrete to withstand internal stresses generated during cement hydration, without cracking [16]. During the process of hydration of cement blended with fly ash, the presence of expanding oxides as CaO and MgO reacting with water form respective hydroxides $Ca(OH)_2$, $Mg(OH)_2$ which have large molecular volume. This leads to internal stresses in concrete followed by cracks consequently [17]. In the case of Kosovo B TPP fly ash the expansion doesn't exceed 1.1 mm, which is in full compliance with the requirements of SIST EN 450-, cl. 5.3. [5]. The testing method according to SIST EN 196-3 [18], limits this soundness up to 10 mm, that our Fly ash, is very sound. The test designs a proportion of mixture of 30%/mass of calcareous fly ash and 70%/mass of cement CEM I.

4.2. Fineness 35.9 %

Fineness or particle size of fly ash is measured, commonly by sieve analysis and is expressed as the proportion of mass in percent of the ash retained when wet sieved on a 0.045 mm mesh sieve. This physical property is very important because the specific surface of fly ash directly influences the compressive and tensile splitting strength of concrete made with a certain percentage of fly ash [19]. The fineness is expressed as the mass proportion in percent of the ash retained when wet sieved on a 0.045 mm mesh sieve. The fineness is determined in accordance with the SIST EN 451-2, Method for testing fly ash-Part 2: Determination of fineness by wet sieving. This standard limits the fineness for category N not to exceed the value 40% by mass, and the Kosovo B fly ash with fineness 35.9% is compatible with the European standard.

4.3. Water for standard consistency 31.8%

This is determined in conformity by the method prescribed by European Standard **SIST EN 451-1, Cl. 5.3.5**. The test result for **CEM I+ Fly** ash is **31.8%,** whilst only for CEM I is **30%**. Even though the European Standard **SIST EN 451-1** does not have any requirement for water for standard consistency, this represents a fluctuation because the use of fly ash in concrete/cement generally should reduce the water demand for achieving the same consistency as cement alone [14].

4.4. Initial setting time 260 min

It represents the time when the cement paste, in our case cement + fly ash starts to stiffen. The test regarding the initial setting time of cement alone shall meet the requirements specified in **EN 197-1** [20], that in our case for CEM I (Portland cement CEM I 42, 5 R) is **185 min**. The determination of the initial setting time of **CEM + Fly ash** is done in accordance with **SIST EN 450-1: 2005+A1:2007 (E)**, respectively **EN 196-3** [18] and the setting time is **260 minutes**, which is smaller than the standards requirement ≤**370 min**, i.e. this is in compliance with the European standard requirement.

4.5. Activity index

Activity index is ratio of the compressive strength of cement paste, mortar or concrete with fly ash to that of compressive strength of control sample. As the compressive strength of the sample with or without fly ash is determined at the age of 28 days and 90 days, under the same curing conditions, here are presented the tests results for respective ages [20].

4.5.1. In 28 days 79.5 %

This is determined in accordance with SIST EN 450-1, cl.5.3, and the testing method conform SIST EN 450-1, cl. 5.3.2, which require the value/ratio not to be less than 75%. The activity index of Kosovo fl ash in 28 days is 79.5% that is in full compliance with the requirements of standard.

4.5.2. In 90 days 87.1 %

This is also determined in accordance with SIST EN 450-1, cl.5.3, and the testing method conform SIST EN 450-1, cl. 5.3.2, which require the value/ratio not to be less than 85%. The activity index of Kosovo fly ash in 90 days is 87.1 % that is in full compliance with the requirements of standard.

4.6 Flexural and Compressive strength of cement CEM I 42.5 R

In the Table V are shown the flexural strength and compressive strength of CEM I 42. 5 R, which is considered to be the referent sample with which we will compare these two mechanical properties of cement mixed with fly ash. The analyses are done in accordance with SIST EN 197-1, which is the European Standard for cement [21], and SIST EN 196-1, which is the European standard for testing cement [22]. Both, flexural strength and compressive strength were tested at two ages, 28 and 90 days.

Regarding the flexural strength the SIST EN 197-1 does not set any requirements, but for compressive strength it does. The mean value of three measurements, at 28 days is 60.6 Pa. This is in compliance with the aforementioned standard.

Table V: Compressive strength and flexural strength of **CEM I 42.5 R**

Strength MPa	**measurement**							**Requirement SIST EN 197-1**	**Test method**
	1		2		3		**Mean**		
Flexural 28 d	**9.1**		**8.1**		**9.1**		**8.7**	-	**SIST EN 196-1**
Flexural 90 d	**9.0**		**9.2**		**9.2**		**9.2**	-	
Compressive 28 d	**60.2**	**59.3**	**60.2**	**59.5**	**62.4**	**61.8**	**60.6**	□**42.5**□**62.5**	
Compressive 90 d	**69.2**	**67.9**	**69.6**	**66.9**	**66.6**	**69.2**	**68.2**	-	

4.7. Flexural and Compressive strength of mixture of CEM I + Fly Ash (SIST EN 450-1, cl. 5.3.2)

The flexural and compressive strength tests of the mixture of **CEM I 42.5 R** and **Fly ash** were also carried out in accordance with SIST EN 450-1, cl. 5.3.2. This in fact is the crucial part of this paper: The replacement of a certain part of cement by fly ash. The tests for determining flexural and compressive strength were performed at two ages: 28, respectively 90 days.

Table VI: Flexural and Compressive strength of mixture of **CEM I 42.5 R + Fly Ash**

Strength MPa	**measurement**							**Requirement SIST EN 197-1**	**Test method**
	1		**2**		**3**		**Mean**		
Flexural 28 d	**6.9**		**7.6**		**6.7**		**7.1**	-	**SIST EN 196-1**
Flexural 90 d	**8.2**		**8.0**		**9.0**		**8.4**	-	
Compressive 28 d	**48.2**	**48.9**	**47.9**	**47.4**	**47.7**	**49.1**	**48.2**		
Compressive 90 d	**59.0**	**60.7**	**59.1**	**58.3**	**59.4**	**59.8**	**59.4**	-	

The comparison of flexural and compressive strengths of mix **CEM I + Fly ash** with the one that is considered as referent, i.e. only cement paste, in fact justify the use of fly ash as cement replacement; the achieved values of these two strengths are very satisfying for utilizing of the fly ash. These tests that prove that Kosovo Fly ash meets the necessary requirements of standards, support the aim of this study for utilizing the fly ash of Kosovo as construction material by using as cement replacement in concrete production industry.

Table VII: Comparison of Flexural and Compressive strength

Strength (MPa)	**Flexural**		**Compressive**	
Age (days)	**28**	**90**	**28**	**90**
CEM I (Referent)	**8.7**	**9.2**	**60.6**	**68.2**
CEM I + Fly Ash	**7.1**	**8.4**	**48.2**	**59.4**

VI. CONCLUSIONS

The energy generation sector in the Republic of Kosovo is profoundly dependant from the energy production by thermal power plants. These plants use lignite as fuel for combustion. Apart from the emissions of greenhouse gases the process of lignite combustion produces around 1 Mt of fly ash annually. A simple calculation shows that since the first operation of first TPP Unit, in Kosovo there were produced more than 27 Mt of unutilized ash, and due to the increase of electricity generation this amount increases daily. Up to now, this ash has been considered as a waste and nothing was done for its utilization. Being so, it represents not only a waste that should be stockpiled, but it also represents an industrial pollutant of environment that must be considered very seriously.

This study aims to turn this industrial waste to an industrial construction product. The study of the chemical and mineralogical composition of Kosovo fly ash proved that many of its properties are in compliance with European Standard EN 450-1, which depicts the properties of the fly ash for use in concrete. The chemical analyses showed many advantages for utilization, but the content of CaO and MgO was higher and represented a fluctuation from the standard(s). This excessive content of these two oxides may lead to unsoundness of concrete made with a certain amount of fly ash. But, through this study of physical and mechanical properties, the test results prove brilliantly that Kosovo fly ash is very suitable for utilization in concrete industry, overcoming the concerns of unsoundness. The test regarding the soundness that was a concern from the chemical analyses showed that Kosovo fly ash is in full compliance with the SIST EN 450 requirements. The standard requires the value to be $\leq$10 mm, and the expansion (soundness) factor of Kosovo fly ash is much lower, $\leq$1.10 mm. Thus, concrete made with Kosovo fly ash will not undergo any undesired expansion that would cause cracks in the concrete. The fineness or particle size of fly ash which is a very important factor because directly affects the rate of hydration process of fly ash (cement) is very compatible with the requirements of standards. The setting time, both initial and final times meet the standard’s requirements. These setting times are of importance because directly affect many properties of concrete such as strength, workability, placement, pumping etc. Regarding the water requirement for standard consistency, although the EN 450-1 does not apply any limit because Kosovo fly ash belongs to fineness class N, Kosovo fly ash show a discrepancy from the general properties of use of fly ash in concrete. Normally for achieving a specific consistency of cement (concrete) the presence of fly ash should reduce the water demand. This is an open issue to be considered for farther studies.

Two mechanical properties, compressive and flexural strength of cement paste made with an addition of Kosovo B fly ash showed very impressive results. These two achieved values of flexural and compressive strength definitely justify the use of Kosovo fly ash in concrete industry as partial cement replacement. The importance of this use is doubled: we will recycle the waste (fly ash) by use in concrete, and indirectly we reduce the CO_2 emissions resulting from the cement production industry.

ACKNOWLEDGEMENTS

The authors would like to thank IPE ProIng, Prishtina, R. of Kosovo for granting access to their data and premises.

REFERENCES

[1] N. K. Koukouzas, C. Vassilatos, I. Glarakis, *Mixture of Lignite Fly ash in Concrete: Physical and Mineralogical characterization*, Case Study from Ptolemais, Northern Greece , *American Coal Association*, 2005.
[2] ASTM, American Society for Testing and Materials, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.
[3] European Standard: Cement. Composition, specifications and conformity criteria for common cements.
[4] M. Qafleshi, L. Aliko, Characterization, Classification and Standardization of Fly Ash of Kosovo Lignite-Fired Power Stations as Industrial Construction Product, *International Journal of Modern Engineering Research, 3(5*), 2013, 3063-3070.
[5] European standard for fly ash in concrete 450-1, 2007.
[6] Independent Commission for Mines and Minerals, R. of Kosovo, http://www.kosovo-mining.org/ kosovoweb/ en/mining.html.
[7] Republic of Kosovo, Ministry of Economic Development, Annual Energy balance of R of Kosovo for the year 2013, 2013.
[8] V. Sofiu, A. Pervizaj, B.Selimi, E. Erxhepi, The Strategy of energy as a good opportunity for protection of the environment in the republic of Kosovo, *International Journal of Modern Engineering Research, 3(2*), 2013, 604-610
[9] Energy Strategy and Policy of Kosovo, EU Pillar, PISG Energy Office.
[10] S. Isufi, *Emission Controls at Kosovo’s Thermal Power Plants, Current and Future Capabilities*, AUK, Pristina, 2010
[11] Kosovo Energy Corporation, KEK statistical data, Strategic development office.
[12] Kosovo Agency of Statistics, Energy Balance in Kosovo Q4 2012, Kosovo, 2013.
[13] *W. von Berg, H. Hukko, Fresh mortars and concrete with fly ash, pp 24,* Champan & Hall, London, 2005.
[14] Berg, Vom, W. :*Kostenorientierter Betonentwurf fuer flugaschehaltoge betone. In: BetonWerk und fertigteiltechnik* 47, S. 401-407,1981.
[15] W. von berg, H. Hukko, Fresh mortar and concrete with fly ash, Rilem Report, (Chapman & Hall, London, 2005).
[16] Brown, P.W.; Berger, R.L.; J.R.; Frohnsdorf, G.; Limitations to fly ash use in blended cements. US. Department of commerce, National Bureau of Standards.
[17] J.L. Alonso, K. Wesche, *Characterization of fly ash, Fly ash in concrete, properties and performance* (Champan & Hall, London, 2005).
[18] EN 196-3, Methods of testing cement- Part 3: determination of setting time and soundness
[19] S. Yazici¸ S. Arel, Effects of fly ash fineness on the mechanical properties of concrete, Sadhana, Indian Academy of Sciences, 37 (3), 2012, 389–403.
[20] Activity related to strength, Rilem report, *Fly ash in concrete, properties and performance* (Chapman & Hall, London, 2005).
[21] Cement-Part 1: Composition, specification and conformity criteria for common cements.
[22] Methods of testing cements-Part 1: Determination of strength.