AN INVESTIGATION ON THE PARTIAL REPLACEMENT OF PORTLAND CEMENT WITH OBILIQ FLY ASH IN CEMENT MORTARS

A THESIS SUBMITTED TO
THE FACULTY OF ACHITECTURE AND ENGINEERING

OF
EPOKA UNIVERSITY

BY

Alban Paja

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
CIVIL ENGINEERING

JULY, 2016

Approval of the thesis:

AN INVESTIGATION ON THE PARTIAL REPLACEMENT OF PORTLAND CEMENT WITH OBILIQ FLY ASH IN CEMENT MORTARS

Submitted by Alban Paja in partial fulfillment of the requirements for the degree of **Master of Science in Department of Civil Engineering, Epoka University** by,

Prof. Dr. ……………...
Dean, Faculty of Architecture and Engineering

Prof. Dr. …………..
Head of Department, **Civil Engineering, EPOKA University**

Prof. Dr. ……………
Supervisor, **Dept., EPOKA University**
Prof. Dr. ……………
Co-Supervisor (if any), **………….. Dept., …………..University**
Examining Committee Members:
Prof. Dr. …………….
………………. Dept., ………….. University

Prof. Dr. …………….
………………. Dept., ………….. University

Assoc. Prof. Dr. ,,,,,,,,,,,,,,,,,,,
………………. Dept., ………….. University

Date: 17.06.2016

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Alban Paja

Signature:

ABSTRACT

AN INVESTIGATION ON THE PARTIAL REPLACEMENT OF PORTLAND CEMENT WITH OBILIQ FLY ASH IN CEMENT MORTARS

Alban Paja
M.Sc., Department of Civil Engineering
Supervisor: Assist. Prof. Dr. Erion Luga

The energy sector is one of the biggest polluters of environment in Kosovo, which is placed in Prishtina city and in the municipality of Obiliq. High level of released gases from power plants with a concentration of acidic materials and self-ignition of coal dust cause significant air pollution. In this study the partial replacement of Portland cement in cement mortars with this Fly ash has been investigated. Six different series of 0.5 water to binder ratio and (0/100, 5/95,10/90,15/85.20/80 and 25/75) fly ash to cement ratios (FA/PC) were used. Several physical, physic-chemical and mechanical properties of the mortars were investigated. The results were compared with those carried out with the control specimens produced with 0,5 w/c ratio and no other additive. Test results show that Kosovo fly ash has good parameter that improve the Compressive strength of cement mortars and concrete by replacing the Portland cement up to 10%. On the other it might affect slightly the water absorption capacity of the mortars. Nevertheless, it can be concluded that the use of Kosovo fly ash in concrete could be a good alternative to be used as a pozzolanic material.

Keywords: Kosovo Fly ash, Portland cements, Cement mortar.

ABSTRAKT

NJE STUDIM MBI ZEVENDESIMIN E PJESSHEM TE CIMENTOS PORTLAND ME HIRIN FLUTURUES TE OBILIQIT NE LLAÇE

Alban Paja

Master Shkencor, Departamenti i Inxhinierisë Ndertimit

Udhëheqësi: Assist. Prof. Dr. Erion Luga

Sektori i energjise qe ndodhet ne qytetin e Prishtines dhe ne komunene e Obiliqit eshte nje nga sektoret me te medhenj per ndotjen e mjedisit ne Kosove. Ndotja e ajrit shkaktohet nga niveli i larte e gazeve te leshuara nga centralet elektrike te cilat kane perqendrim te larte te materialeve acide dhe nga djegia e qymyrit. Ne kete studim eshte shqyrtuar zevendesimi i pjesshem i cimentos Portland ne llac duke perdorur hirin fluturues dhe jane perdorur gjashte seri te ndryshme 0.5 te ujit ne perpjestim me lidhesen dhe (0/100, 5/95,10/90,15/85.20/80 dhe 25/75) Hiri fluturues ne raport me cimenton. Gjithashtu eshte bere hulumtim ne vetite fizike dhe fiziko-kimike te llacit. Rezultatet u krahasuan me rezultatet qe u nxorren nga mostrat kontrolluese te prodhuara ne nje raport 0.5 w/c pa asnje produkt shtese. Rezultatet e testit treguan se hiri fluturues i Kosoves ka parametra qe permiresojne forcen ngjeshese te llacit dhe betonit duke I zevendesuar me cimento Portland deri ne 10%. Nderkohe mund edhe te ndikoje lehte ne kapacitetin thithes te ujit te llacit. Megjithate si perfundim mund te themi se perdorimi I hirit fluturues I Kosoves ne beton mund te jete nje zgjedhje e mire per tu perdorur si material pozolanik.

Fjalët kyçe: Hi fluturues, Llaç, Cimento Portland .

Dedicated to my family

ACKNOWLEDGEMENTS

I would like to express my special thanks to my supervisor Assist Prof. Dr. Erion Luga for his continuous guidance, encouragement, motivation and support during all the stages of my thesis. I sincerely appreciate the time and effort he has spent to improve my experience during my graduate years.

I am also deeply thankful to Epoka University.

I deeply thank to Kosovo Electro Energetic Corporate, especially to Eng. Shaban Myftari for their support in providing the raw material (Fly ash) for this study.

TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

FA	Fly ash
PC	Portland cement
OPC	Obtain Portland cement
KEK	Electro energetic Corporation of Kosovo

CHAPTER 1

INTRODUCTION

1.1 Fly ash.

Fly Ash (FA) is a solid material part of coal ash and it is formed from the burning of pulverized coal in electric power plants. In short we may say that fly ash is the dust that is collected as a result of combustion in smokestacks. While producing FA, the coal in a high temperature passes in the furnace and the carbon is burned off whereas other impurities are melted from the high temperature. After the pulverization the coal enters in a boiler burning in a temperature that reaches up to 1500 degrees Celsius. The combined material is transported to zones with low-temperatures, where it hardens as sphere-shaped pieces of glass. Some of the mineral substances are joined and collected forming bottom ash, but most of it goes out with the vent gas stream and is called "fly ash". Then the ash is removed from the gas by mechanical strainer.

Fly ash can react with $Ca(OH)_2$ at room temperature and can act as pozzolanic materials. Their pozzolanic activity is due to the presence of SiO_2 and Al_2O_3 in amorphous form. Fly ash is a finely-divided amorphous-silicate with variable amounts of calcium and when mixed with Portland cement and water, will react with the calcium hydroxide released by the hydration of Portland cement to produce various calcium-silicate hydrates (C-S-H) and calcium-aluminate hydrates. Fly ashes which have larger amount of calcium will show cementitious behavior by reacting with water to produce hydrates in the absence of a source of calcium hydroxide [Wesche, (1991)].

The usage of Fly Ash is very important for the production of concrete cement and it is used in different ways and in different constructions. The two processes most widely used in coal fired power plants are the pulverized coal combustion (PCC) and the fluidized bed combustion (FBC). Most of the fly ash from PCC power plants can be recycled and the products can be used in the cement industry, in road construction and in other places [Thomas, (2007)].

1.2 Types of fly ashes

According to their origin, Fly Ashes may be divided in two categories:

1) Class C usually derives from coal that produces an ash with higher lime content, usually more than 15% or to 30%. The upraised CaO might give unique self-hardening features to Class C. This class of fly ash is pozzolanic and also can be self-cementing and also this class besides having pozzolanic characteristics also has some cementitious ones.

2) Class F comes from the burning of anthracite or bituminous coal which is produced in low lime content, usually fewer than 15% and contains combination of alumina iron and silica. This class of ash is very pozzolanic and this makes it reacting with extra lime produced in the hydration of Portland cement. FA has chemical and mineralogical composition. These characteristics hinge on the composition of the coal burned in the power plant. Fly Ashes are in the form of glassy particles and only a small amount is in the form of crystals [ASTMC618].

1.2.1 Classification of fly ash

Table 1. Dosage levels of Fly Ash.

Level of Fly Ash % by mass of total cementations material	Classification
<15	Low
15-30	Moderate
30-50	High
>50	Very High

Table 2. ASTM C 618 Specifications for Fly Ash [AASHTO M 295].

Class	Description in ASTM C 618	Chemical Requirements
F	Fly ash normally produced from burning anthracite or bituminous coal that meets the applicable requirements for this class as given herein .This class of fly ash has pozzolanic properties.	. $SiO_2 + Al_2O_3 + Fe_2O_3 \geq$ 70%
	Fly ash normally produced from lignite or sub-	

C	bituminous coal that meets the applicable requirements for this class as given herein. This class of fly ash, in addition to having pozzolanic properties, also has some cementitious properties.	$SiO_2 + Al_2O_3 + Fe_2O_3 \geq$ 50%

Table 3. Chemical properties of Fly ash

Chemical Properties	Class F –CaO containing > 10%	Class C –CaO containing < 10%
SiO_2	43.6-64.4	23.1-50.5
Al_2O_3	19.6-30.1	13.3-21.8
Fe_2O_3	3.8-23.9	3.7-22.5
CaO	0.7-6.7	11.5-29.0
MgO	0.9-1.7	1.5-7.5
NaO	0-2.8	0.4-1.9
losses	0.4-7.2	0.3-1.9

1.3 Physical properties of fly ashes

The shape, the size distribution, fineness, and thickness are the physical properties that influence the properties of fresh and solidified concrete. The color of fly ash and the amount used may affect the color of the resulting concrete. According to ASTM C 618 besides the fineness of fly ashes, strength activity index, water requirement, soundness, uniformity, and moisture content are also to be investigated as physical properties of fly ashes. The strength that physical and chemical properties of fly ash possess changes considerably depending on the objects used for production. The cause of all these changes might be the fusion of some particles of burned coal, the minuteness in grinding, the burning scale and efficiency, the kind of burning supply and the collecting system of fly ash. The physical properties of fly ash are more effective than those of chemical properties at the performance of fresh coal. Beside this the Fineness of fly ash affects the rate of pozzolanic activity and the workability of the concrete [Erdogan, (1997)].

1.3.1 The shape and the size of grain

In most cases fly ash contains Fly ash contains predominant solid and some hollow units of round shape. The hollow particles, called chemosphere's, may make up as much as 5% by weight or 20% by volume of fly ash. These are filled with nitrogen and carbon dioxide. Large concentrations of these particles are not desirable in ashes used for concrete since they are lighter than water and tend to float during the finishing operation leading to dark colored streaks on the concrete surface. The size of fly ash varies from 1 to 150 μm, the majority (75 percent or more) being less than 45 μm. The range of particles in any given fly ash is largely determined by the nature of fly ash assortment system and the efficiency of plant operation. The fly ash from boilers where mechanical collectors are employed is coarser than that obtained by using electrostatic precipitators.

1.3.2 Fineness

The fineness of fly ash influences the pozzolanic activity and the fresh concrete manufacturing. Also it influences the water demand of concrete and the dosage of air absorption. Generally, the use of fly ash normally decreases the water content and improves workability of concrete but an ash with very high fineness such as with over 95% passing the 45 μm (No.325) sieve may involve a rise in water over that of the control mixture by 1 to 3%, especially when the mixture has a low water-cement ratio. A high amount of fineness increases the demand for air-entraining admixture.

1.3.3 Density

Normally, fly ash's density varies from 2.1 to 2.7 g/cm^3. The density of fly ash samples is checked regularly to determine variations due to hangs in plant efficiency or coal source. The density of fly ash does not have many effects on concrete's properties. Major changes in density of fly ash are compensated for by adjusting concrete batch weight to maintain yield.

1.3.4 Color

Fly ashes may have different colors. Their color depends on the place where it is produced and the way it is produced. Generally, fly ash has a grayish color, when it is in bulk. However, its color may range from light tan to dark gray depending on the type and quality of the coal and on the boiler operation. The color of fly ash becomes darker with increasing proportions of unburned coal composed with fly ash as carbon elements. Besides carbon, other elements such as iron may have an effect on color. High iron content produces a tan colored ash. Most fly ashes are similar in appearance to Portland cement, usually of slightly darker color.

1.3.5 The Activity resistance indicator

This indicator shows the fly ash presumed capacity from the pozzolanic reaction. Different elements such as silica, alumina and iron that can be melted in particles and in quantity are important elements that determine the degree and the norm of pozzolanic reaction. The indicator of activity resistance is decided in 1994 as it was defined in the part 7.3.4 ASTM C311-94a. For fly ash this value should not be less than 75%.

1.3.6 Water requirement

Water requirement of fly ash is affected by the fineness of its particles. Cement paste made with very fine ashes require slightly higher water content than those made with coarse ashes.
However, the small size and spherical form of the particles usually cause a decrease in the water content of the concrete required for a given degree of workability as compared to that made with an equivalent paste made without fly ash.
Water requirement of fly ashes is specified according to ASTM C 311. According to ASTM C 618, the water necessity of fly ashes should not be more than 105% of control pastes.

1.3.7 Soundness

Fly ash mixtures are not expected to show great expansions or contractions that will be harmful in practice. ASTM C 618 limits the maximum percentage of expansion or contraction of these mixtures as 0.8. The test is showed in agreement with Test Method mentioned in ASTM C 311. The size and particle size delivery of fly ash particles should possess a certain amount of uniformity.

1.3.8 Uniformity.

The size and distribution of fly ash particles should be consistent. The uniformity of fly ashes is checked by determining their fineness and density.

According to ASTM C 618, the fineness and density of individual samples of fly ashes should not vary by more than 5% from the average recognized by ten preceding tests, or by all tests if the number is less than ten.

1.4 Fly ash of Obiliq, Kosovo

The energy sector is one of the biggest polluters of environment in Kosovo, which is placed in Prishtina city and in the municipality of Obiliq. High level of released gases from power plants with a concentration of acidic materials and self-ignition of coal dust cause significant air pollution. There are many factors which cause pollution in the entire area of KEK which over time has been contaminated with phenol and in the river of Sitnica such as: waste water from the technological process, water flowing from opencast mines, the bad situation of reservoirs and basins of water phenol, phenol concentrated in the area of gasification and runoff from the rain. Additional problems are dumped accumulating more than 40 million tons of ash and about 242 hectares are occupied of arable land, landfill from TC Kosovo- A and 150 ha dump TPP Kosovo-B, and open pits during mining surface of coal exploitation. Many activities and electric generation in the past and now days are doing heavily polluting, air, water, soil, noise and denominations of natural degradation of biodiversity in the municipality of Obiliq. In the industrial area of KEK, large areas of land are covered with overburden deposits from previous mining activities, dumps out power plants, solid waste liquid contaminates and sanitary landfill.
In the area where Kosovo B is separated from Kosovo A solid waste are dominant and this is observed during the entire coal transport line and particularly in locations where coal becomes crumbling. Waste in large quantities in KEK are the products of combustion of coal-ash dump ash liabilities of B which is located near the separation and Kosovo B together with wastelands and lagoon covers an area of 234 ha. Now coal and fly ash from TPP Kosovo A &Kosovo B hydraulically transported in the empty places of S. Mirash. So it is necessary to find a solution for those materials which are thrown in fields and those fields are not used any more from people

because they are full with fly ash material. Waste can be used to produce new products or they can be used as admixtures so that natural resources could be more efficiently used and the environment will be protected from waste deposits. These industrial wastes are dumped in the nearby land and the natural fertility of the soil is spoiled. Fly ash is the finely divided mineral or an artificial pozzolant residue resulting from the combustion of ground or powdered coal in electric power generating thermal plant. Fly ash is a beneficial mineral admixture for concrete. It influences many properties of concrete in both fresh and hardened state and it does the utilization of waste materials in cement. Concrete industry reduces the environmental problems of power plants and decreases electricity generation costs [Krasniqi *et. al.*, (1996)].

The present day world is witnessing the construction of very challenging and aesthetic structures. Being the most important and widely used material, concrete is called upon to possess very high strength and sufficient workability properties. Efforts are being made in the field of concrete technology to develop such concretes with special characteristics. In the present experimental investigation the fly ash has been used to study the effect on compressive and split strength of concrete. So it is necessary to use this material in concrete and to decrease the amount of field with waste fly ash. Recent studies show that if we mix fly ash with the cement we can produce a stronger concrete and we can reduce the throwing materials in the environment. Fly ash is a feasible material because its forms and particles are spherical and this makes the concrete possible to stream easily. This workability decreases the ratio of cement and water and as a result we see that we can create a stronger concrete in suppression. Also the spherical particles of fly ash help in strength and durability. The world today is testing many materials making them not pollution factors for the environment and using these materials in the production of a new material that will be stronger but with the same characteristics in flexibility and in pressure force.

1.4.1 A brief history of the energetic system in Kosovo

KEK area located between the Sitnica River valley in the east at an altitude of about +525 meters and a ridge that is extended south at an altitude that goes to +750 meters, while on the west side continues to surround the valley of the river Drenica with an altitude of expansion of about +550 meters. Location is built in separation B and it is located in the industrial area of TC Kosovo B, in the north with the ash dump TPP Kosovo B, in the west with Sitnica River, east and south of Obilic area defined by the mines and Kosovo A. The area of Separation B is located in the municipality of Obiliq about 10 km west of the city of Prishtina. Obiliq municipality lays in the central part of Kosovo, in the coordinate's 41 degrees north latitude 42o and 21o 5 geographic eastern geographic lengths. It is located between Plain of Kosovo near the rivers Sitnica and Lab and it has a good geographical position which is not limited to: Pristina, Kosovo Polje, Glogovac, 12 Vushtrri and Podujeva. The municipality of Obiliq extends over an area of 105 km² and occupies about 1% of the total territory of Kosovo. This area constitutes a different relief with mountainous terrain, surface flat and fertile land. The central part is around river Sitnica and there are the western hills of the relief of the mountain valley Qyqavica. It is an industrial center with two power plants and large coal reserves which lie between the river and the valley of the river Drenica in a length of about 32 km in a north-south direction and a width of about 12 km. Kosovo's energy system has a history of several decades. In 1922 Kosovo inaugurated its energy development with the opening of the first underground mine coal. Today Mirash, Bardh mine, west Sibovc mine and coal are the main sources used for energy in Kosovo, providing a total annual production of approximately 7 million tons of coal. In 1960 construction began using the first power plant based on coal. Kosovo A power plant was the first unit and it had a capacity of 65 MW. By 1975 within the Kosovo A were built four other blocks, reaching a total capacity of 800 MW. From 1977 to 1984 the second plant was built in Kosovo B with a total capacity of 678 MW and two generating units. For a long time Kosovo was an integral part of the energy system of the former Yugoslavia. During that period the production of energy in Kosovo was focused on the production based on coal (thermal) with a small contribution to production based on water (hydro). Kosovo's own supply of power was originated from its own power station and also from other sources of energy production located throughout the territory of the former Yugoslavia. In the '90s during the breakup of Yugoslavia, the country's energy system was poorly maintained or there were no sufficient financial sources. From 1989 to 1999 the majority of local experts were dismissed from their jobs. However, in mid-June 1999 during the last war with Serbia, the Albanian workers began to return to Kosovo and were able to return to their places of work. After a decade of neglecting, the energy sector firstly received investments from international institutions and then by local institutions in order to revive the country's energy capacity. In the postwar period power sector received an infusion of great International assistance. Although there are no exact figures available, it is estimated that since 1999 there have been invested more than 1 billion euros. However, these funds were not sufficient to solve the problems of the country's energy sector [Naik *et. al.*, (1987)].

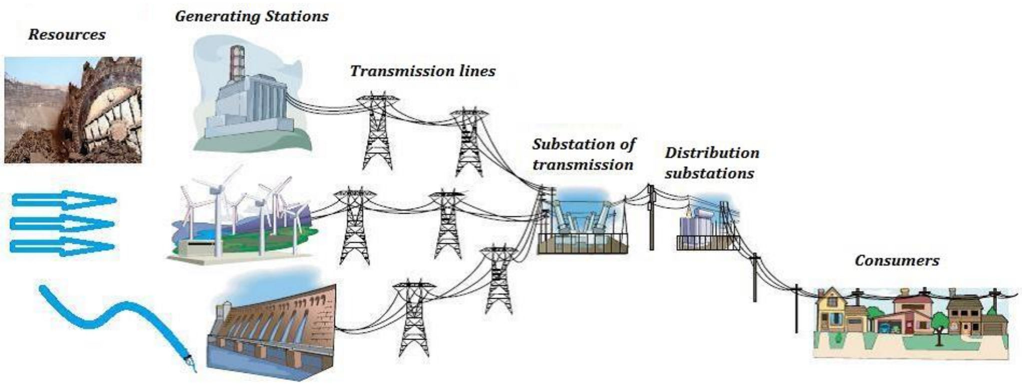


Figure 1. Power distributions [Naik *et. al.*, 1987].

1.4.2 Surface Mines

The extraction of coal (lignite) in coal basin known as Kosovo Basin started in 1922 with the underground method. First, coal was exploited by mining KOSOVO, and then from mining: Dardhishtë, Sibovc, New shafts and Babushi Muhaxher. This form of coal mining continued until 1956 and then in the Mirash mines in 1956 initially started the removal of overburden, whereas the first tons of coal from this mine were conducted in 1958. With the increase of the capacity was born the need for the opening of the mine Bardhi. The Bardhi mine opening started in 1964 with the removal of overburden and the first exploitation of tons of coal from this mine occurred in 1969. Since 1922 up to December 2009 from all these mines within the basin coal (Lignite) a total of 300.1 million tons of coal are exploited.

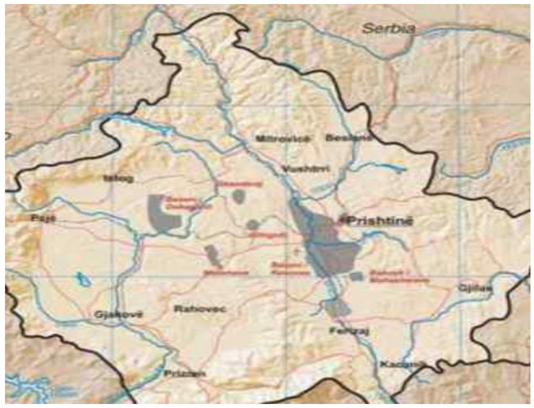


Figure 2. Kosovo's line sources [Krasniqi *et. al.*, 1996].

The current organization of production of coal within the KEK is: COAL Production Division, within this division there are three main work fronts:

• Existing mines of eastern and western sector

• Sector Sitnickom

• The new mine South-Western Sibovc

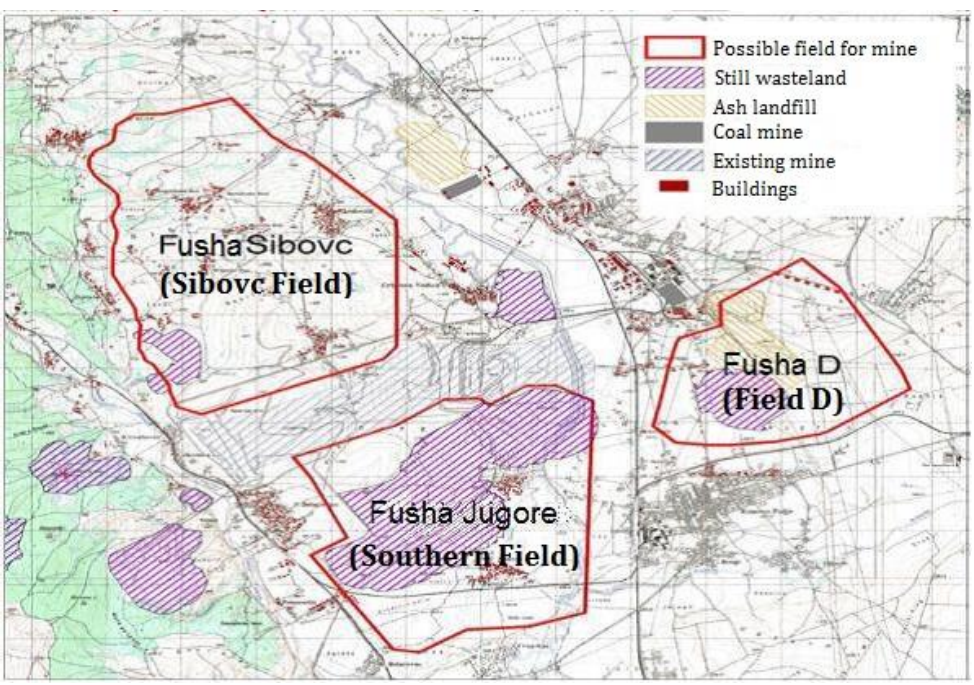


Figure 3. Map of Kosovo lignite basin [www.kek-energy.com].

Table 4. Map of Kosovo lignite basin [www.kek-energy.com].

Field of Sibovcit	South field	D field	
Geological reserves of lignite / Exploitable	990 mt / 830 mt	537 mt / 370 mt	395 mt / 280 mt
TC with sufficient capacity:	2000-2500 MW	Ca. 1000 MW	Ca. 600 MW
Overburden / coal m3 /	0.9:1	2.8:1	0.9:1
Net calorific value	8300 kJ/kg	8000/8300 kJ/kg	7300 kJ/kg

Current existing mine reserves are 7.1 million tons and are expected to be completed during 2012 [www.kek-energy.com]. Reserves in Sitnica sector are 7.4 million tons of new mining reserves in SWS are 123.4 million tons. These reserves are intended to supply the existing power generation capacity by 2024. Average annual production is currently around 8.0 million RPD per year. Lignite is the main source of energy in Kosovo and 98% of lignite mining dedicated to the production of electricity in KEK-s, whereas electricity production depends entirely on the supply of lignite [www.kek-energy.com].

Figure 4. Coal mining (coal) Obiliq Kosovo [www.kek-energy.com].

1.4.3 Power Plants

Energy Generation Division is composed of PP "Kosovo A", "Kosovo B" and Chemical separations, which are located in the vicinity of Kastriot. Kastriot is located about 8 km away from Pristina, the capital of Kosovo.

1.4.4 The power plant "Kosovo A"

"Kosovo A" consists of five units known as A1, A2, A3, A4 and A5. A1 block was built on 03.10.1960 and this block was put into operation in 21.10.1962 with a generating capacity of 65MW. Block A1 boiler was equipped by the "Babcock" (Germany) and the turbines by "Westinghouse" (America). Block A2 courses began to rise in 1962 and started with the production of 125MW power 20.05.1965. Block A2 furnace was equipped by the "Babcock" (Germany) and the turbines by the "General Electrics" (America). A3 started on 18.04.1970 with 200MW power and it was equipped with a boiler from "Rafako" (Poland) and the turbine with the generator from "leningradskie Metaljurgski Zavod" the former Soviet Union of Socialist Republics (USSR-Russia). A4 started the production on 05.15.1971 with a power of 200MW and Block A5 which started producing in 08.07.1975 with installed power incapacity of 210MW. Equipment's for the production of these two blocks are the same as at Block A3. A3, A4 and A5 are operational. According to the current plan it is estimated the use of two units where one of them is a "hot" spare due to their low readiness, which is a consequence of their age. Blocks A1 and A2 are out of work without a defined status and according to current plans, they will remain so until the end where along with other units it is expected to become their decommission. Annual electricity production from Kosovo A is about 1500GWh [Naik *et. al.*, 1987].

Table 5. Annual electricity productions from Kosovo A [Naik *et. al.*, 1987].

Generation units	**Installed powered (MW)**	**Time of construction**	**The first work release**
A1	65	1960-1962	21.10.1962
A2	125	1962-1965	20.05.1965
A3	200	1966-1970	18.04.1970

A4	200	1967-1971	15.05.1971
A5	210	1971-1975	08.07.1975

Figure 5. The power plant "Kosovo A" [www.kek-energy.com].

1.4.5 Power plant "Kosovo B"

Construction of the power plant "Kosovo B" is performed by the consortium of Alstom Atlantique-Man and gee. "Kosovo B" consists of two working units (blocks) known as B1 and B2. The first block (B1) of the plant is put into operation with effect from 09.10.1983 with 340MW, whereas the second block (B2) in 07.14.1984 power of 339 MW. Both units are functional and have a good standby time. With the investments which are made continuously in this plant there is seen a significant progress on the condition of the units, even though they have a seniority of 25 years in a high technical readiness. 2008 and 2009 are the years when this plant has achieved a record production in its history since its construction in 1984. Annual electricity production from TC Kosovo B is about 3650GWh [www.kek-energy.com].

Table 6. Power plant "Kosovo B

Generation units	Installed powered (MW)	Time of construction	The first work release
B1	339	1977-1983	10.09.1983
B2	339	1977-1984	14.07.1984

Figure 6. Power-plant "Kosovo B" [www.kek-energy.com].

1.4.6 Technological scheme of the production system

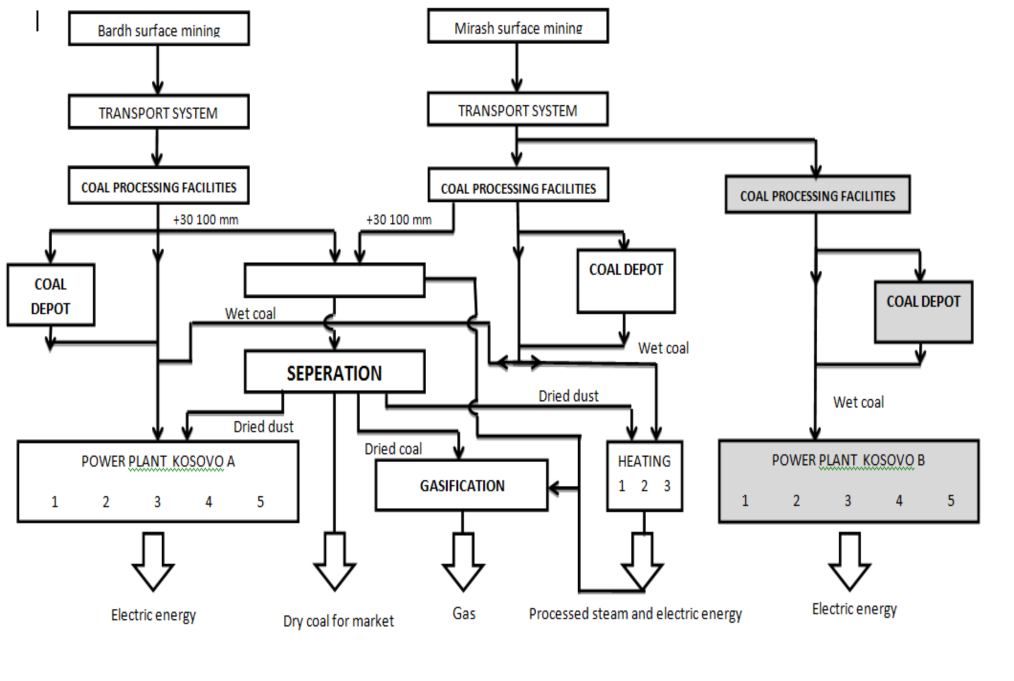


Figure 7. Technological scheme of the production system [www.kek-energy.com].

In this *(Fig.7)* are shown the steps of production and transportation of fly ash from thermos central Kosovo A to Kosovo B and is showing the producing the fly ash from coal burning to its final station, So it shows the production of coal to fly ash and in the last step it is shown the deposition of fly ash in field and in the end we can get the electric power.

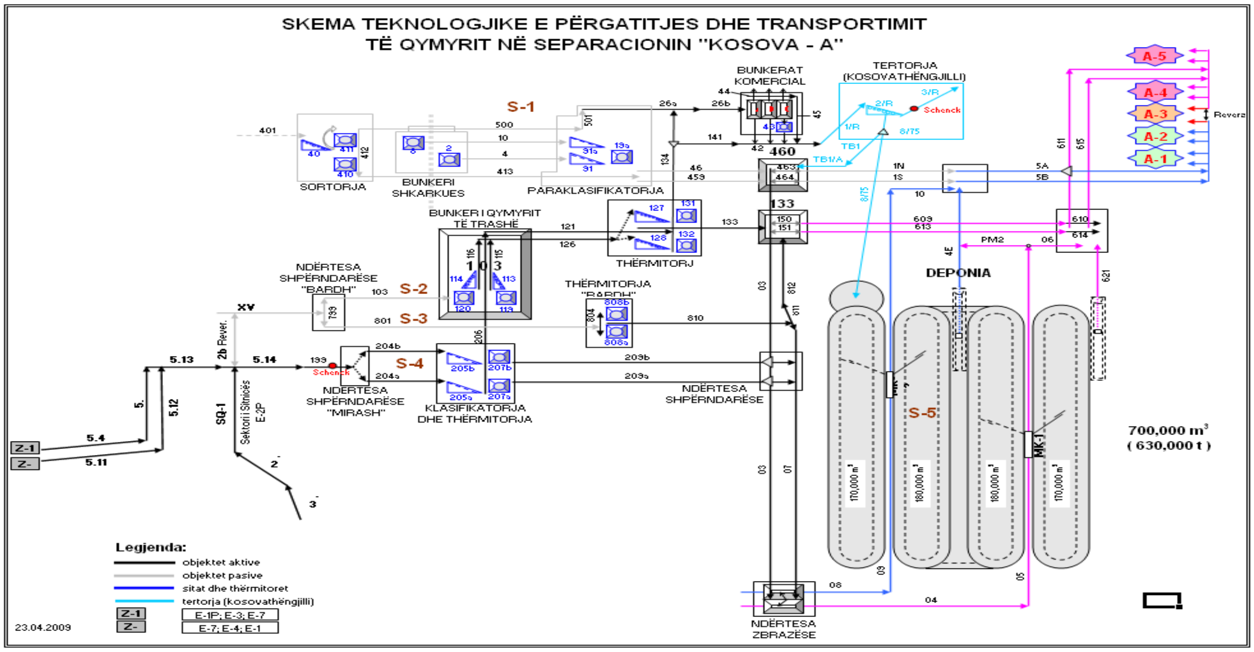


Figure 8 .Technology system of transportation and separation of Fly ash in Kosovo A [www.kek-energy.com].

In the first one the coal is entering to the clinker which is call coal pulverizes and then it is passed to the tubes and enters to the Furnace bottom ash. After passing to the steam out it is put to turbines with both high and low pressure and it goes to the electrostatic precipitation. After cooling with water it comes out and it storages in the field. So in field it is waste fly ash storage.

This is a schematic layout of a coal-fired electrical generating station. In the production of fly ash, coal before being blown with air into the burning zone of the boiler it is first pulverized in grinding mills. The basic material of production of fly ash is coal. Basic materials like coal are taken from the TREPCA mine. TREPCA is a city which its position is near to Serbia country. They are loaded to the truck and behave as raw materials in a thermal central of Kosovo, and then it enters the furnace to be separated from other material. The separation part happens because coal has unnecessary products which we don't want to use in thermos central in electric power. After separation of unnecessary products the coals enter in small pieces to the separation machine of materials. In that machine small pieces of coals enter to the clinker where they are heated and caught to the temperature of 1500 °c. After heating, the inorganic compound comes out from clinker because the filters take up all the inorganic compounds. After the coal is molten, it goes to the cistern where it is cooling with water and the air becomes a small particle. After cooling, the particles pass from cistern to ventilation pipes and from there it is deposited to the last section of storage. In the storage the fly ash comes out from the pipes and it deposited in the field. In field fly ash is in small particulars and in spherical particles. From there the machinery comes and takes all the fly ash collection and deposits it in a plant area where it is ready for selling to the cement companies. Titan cement and KRUJA cement have taken all of Fly ash collection to use it like a chemical product in cement material. In one day the thermos central of Kosovo produces 1800 tons/day and in one year it produces 6 million tons. So as it seems a lot of fly ash is coming in field from thermos centrals so it is necessary to use this amount of fly ash to produce a concrete and to use them as mineral admixtures.

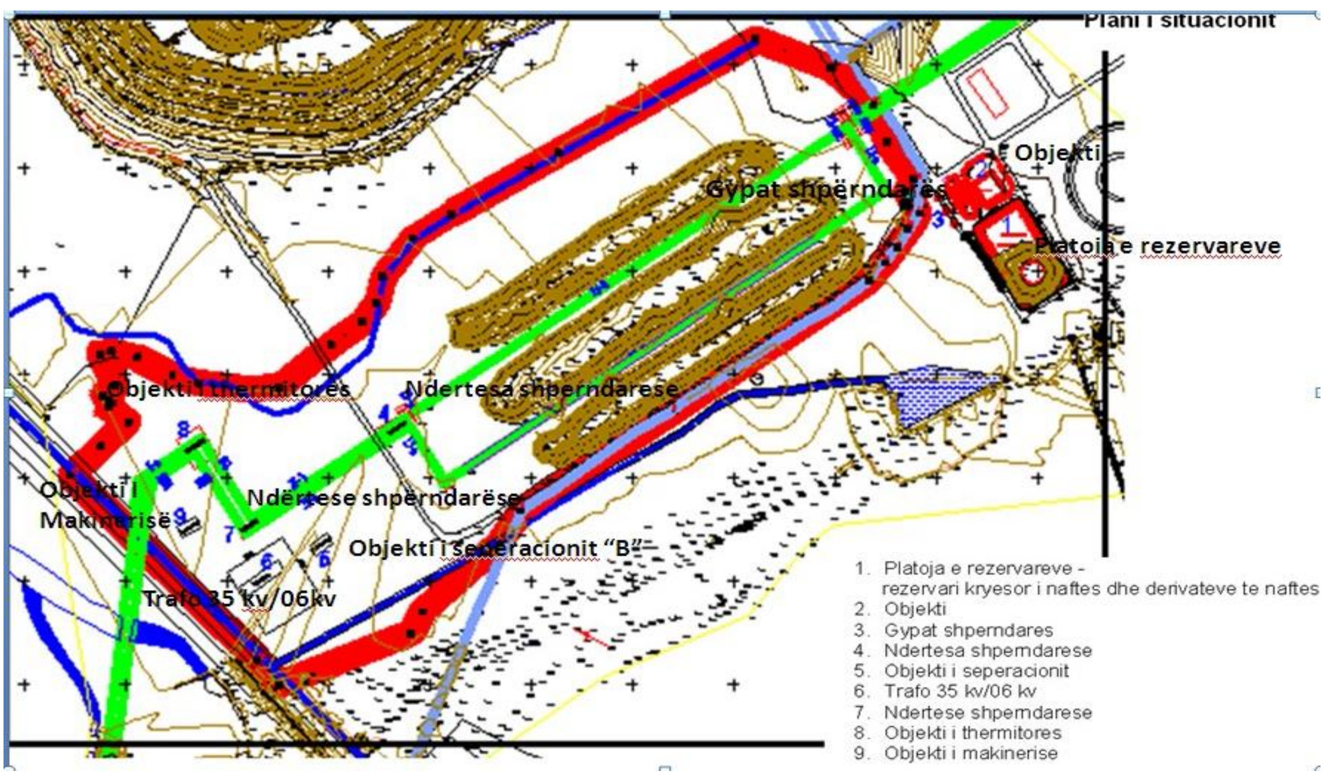


Figure 9. Collection of fly ash material in field [www.kek-energy.com].

(Fig 9) shows all the maps in Kosovo thermos-central electric power and the fields with fly ash waste material. The yellow color in the *(Fig 9)* is the fly ash material. So it is very large amount of fly ash thrown to the field www.kek-energy.com.

1.5 Literature review

1.5.1 Effect of Fly-Ash Type on Concrete Strength

The principal distinction between fly ashes is that some are cementitious even without Portland cement and these are the supposed ASTM Class C, often created at power plants that blaze subbituminous or lignite coals. Generally, the rate of strength advancement in cements has a tendency to be just hardly influenced by high-calcium fly ashes.

[Yuan *et al.,* (1983)] studied the concrete's strength advance with high-calcium fly ash and in its absence (CaO = 30.3 wt. %). They established the amount of strength improvement of fly ash cement to be practically similar to that of the control concrete, with or without air entrainment. Class F fly ashes were the first to be inspected for use in cement. The majority of what has been composed on the conduct of fly-ash concrete inspects only Class F ashes concrete. Moreover, the ashes utilized in most of the early work originated from power plants and were in small size, contained not scorched fuel, and were frequently non active pozzolans. These ashes that were utilized as part of cement and balanced by basic substitution indicated slow rates of strength improvement. This prompted the wrong perspectives that fly ash lessens the quality at all ages.

[Gebler *et al.,* (1986)] assessed the impact of ASTM Class F and Class C fly ashes from 10 distinctive sources on the quality improvement of cements under various settings. The tests demonstrated that solid containing fly ash could deliver acceptable compressive quality improvement. The impact of the class of fly ash on the long term quality of cement was not substantial. Generally, compressive quality advancement of cements containing Class F fly ash was more helpless to decrease temperature than concrete with Class C fly ash or the control cements. Gebler and Klieger inferred that Class F cements needed more introductory wet curing for long term, air-cured compressive quality improvement than did cements containing Class C fly ash.

1.5.2 Effects of Temperature and Curing Regime on Strength Development in Fly-Ash Concretes

According to [Williams *et al.,* (1982)] at the point when concrete with Portland cement is preserved at temperatures that are more than 30°C, an expansion in quality happens at early ages, however a stamped diminish in quality in the full grown concrete. Concretes having fly ash and control cements act distinctively the 28-day strength.

1.5.3 Effect of Fly Ash on Creep Properties of Concrete

[Ghosh *et al.,* (1981)] analyzed bituminous fly ashes of various carbon substances and fineness values in cements at ostensible quality levels of 20, 35, and 55 MPa (water/concrete proportion of 1.0, 0.4, and 0.2). Every concrete was proportioned for identical quality at 28 days. Fly ash cements demonstrated fewer creeps in the most of examples than the mention cements. This was ascribed to a generally higher rate of strength increase after the loading period for the fly ash cements than for the reference cements. [Yuan *et al.,* (1983)] researched creep of great strength cement containing a high-calcium fly ash and demonstrated that solid containing 30 and 50% fly ash displayed more creep than either the control concrete or a solid with 20% fly ash

1.5.4 Effects of Fly Ash on the Durability of Concrete

Progressively, cement is chosen for use as a development material in influential or conceivably forceful situations. Solid structures have been presented to the activity of seawater. Nowadays, the requests on cement in marine situations have expanded significantly, as solid structures are utilized as a part of cold, mild, and tropical waters to contain and reinforce the tools, individuals, and results of oil and gas investigation and fabrication. Solid structures are utilized to contain atomic reactors and must fit for comprising gasses at hoisted temperatures and weights under crisis conditions. Cement is progressively being in contact with sulfate and acidic waters. The utilization of fly ash as a solid material assumes a part, and a comprehension of its impact on solid sturdiness is fundamental to its right and efficient presentation.

1.5.5 Effects of Fly Ash on Permeability of Concrete

Various examinations have contemplated the impact of fly ash on the relative penetrability of solid funnels containing fly ash relieved for concrete in measures of 30 to 50%. According to [Davis, (1954)] penetrability tests were made on 150 × 150-mm barrels at the ages of 28 days and 6 months. From this information it is seen that the penetrability of the solid was straightforwardly identified with the amount of hydrated cementitious material at a certain time. Following 28 days of curing the fly-ash cements were more penetrable than the control cements. At 6 months, this was turned around. Extensive impenetrability had grown, probably as an aftereffect of the pozzolanic response of fly ash. [Short *et al.*, (1982)] provided details regarding the dispersion of chloride particles in arrangement into Portland mixed bond glues and found the accompanying estimations of dissemination coefficient (Dc) for various concrete sorts.

Table 7. Estimations of dissemination coefficient (Dc) for various concrete

Type of cement	Dc Value (x10 $^{-9}$)cm^2/s
Normal Portland	44.7
Sulfate -resisting	100.0
Fly ash/Portland	14.7
Slag/Portland	4.1

In conclusion it was determined from this information that slag and fly-ash bonds were more viable in restricting chloride dispersion in glues than were typical or sulfate-opposing concretes.

1.5.6 Abrasion and Erosion of Fly-Ash Concrete

Under some conditions, cement is exposed by whittling down, scratching, or the sliding activity of vehicles, ice, and different articles. While water streams over solid surfaces, corrosion may happen. So, despite the kind of test completed, the scraped area resistance of cement is generally observed to be relative to its compressive quality. So also, at steady droop, imperviousness to corrosion enhances with expanded bond substance and quality. It might be foreseen that fly-ash concrete that is not completely or deficiently cured might indicate lessened imperviousness to scraped spot. [Carrasquilo, (1987)] inspected the scraped spot resistance of cements containing no fly ash, 35% ASTM Class C fly ash, or 35% ASTM Class F fly ash. The verified samples were thrown from cements having comparative qualities, air substance, and cementitious materials substance. The scraped spot resistance of cement containing Class C fly ash was more noteworthy than that of cement containing Class F fly ash or no fly ash. The last two showed around equivalent scraped spot resistance; estimation depended on the profundity of wear.

[Naik *et al.*, (1992)] have done an examination of the compressive quality and scraped spot resistance of cement containing ASTM Class C fly ash. They balanced solid blends to have concrete substitution in the scope of 15 to 70 wt. % fly ash. The water/cementitious resources proportion fluctuated from 0.31 to 0.37. Their outcomes demonstrated that the scraped area resistance of cement containing ≤30% fly ash was like that of the control concrete. Although, the scraped spot resistance of cements containing >40% fly ash was lower than that of control cement without fly ash.

1.5.7 Effects of Fly Ash on Alkali–Aggregate Reactions in Concrete

[Stanton, (1940)] found that alkali–aggregate responses (AARs) created extension and harm in some cements. He stated that the impacts could be lessened by adding finely ground receptive materials to the solid blend. Hence, an assortment of characteristic and manufactured pozzolans and mineral admixtures, including fly ash, were observed to be compelling in diminishing the harm brought on by AARs. The adequacy of fly ash in decreasing extension because of AARs gives off an impression of being constrained to responses including siliceous totals. According to [Swenson *et al.*, (1960)] a type of AAR known as the alkali–carbonate response is generally not responsive to the expansion of pozzolans

The importance of fly ashes in lessening development by AAR can be condensed as:

Significant distributed information demonstrate that low-calcium fly ash with alkali substance of less than 4% are viable in decreasing extension created by alkali–silica responses when the fly ashes are utilized at a substitution level as a part of the scope of 25–30%. High-volume fly ash cement is exceptionally compelling in such manner.

The utilization of high-calcium ashes has less consideration; henceforth, the foundation data applicable to their utilization is not well created. If they are going to be utilized, there is some sign that viable substitution levels might be higher than those for low-calcium ashes.

The system and subtle elements of the control of extension brought about by alkali–silica responses are not completely agreed. There are still many researches to be performed before an attractive comprehension can be created.

1.5.8 Effects of Fly Ash on the Corrosion of Reinforcing Steel in Concrete

Nowadays, an important worry has been the consumption of steel fortification in fly-ash solid structures presented to chloride particles from thawing salts or seawater. If the cover of cement over steel fortification is adequately thick and impermeable, it will regularly give sufficient insurance against consumption. The defensive impact of the solid spread is of both a physical and a chemical nature and capacities in three ways:

It gives a basic medium in the quick region of the steel surface.

It offers a physical and substance boundary to the entrance of dampness, oxygen, carbon dioxide, chlorides and other agents.

It gives an electrically resistive medium around the steel.

Under alkaline conditions (pH higher than ~11.5), a defensive oxide film will shape on a steel surface, rendering it insusceptible to further consumption.

At the point when solid carbonates and the profundity of carbonation come to the steel–concrete limit, passivation might be lessened and consumption may happen if adequate oxygen and dampness achieve the metal surface. Chlorides or different particles may likewise undermine the defensive impact of passivation and energize consumption.

Technical Committee on Corrosion of Steel in Concrete (1974) revealed a statement that has a new perception on this subject:

The effectiveness of the (concrete) spread in avoiding consumption is subject to numerous elements which all in all are alluded to as its "quality." In this setting, the "quality" suggests impenetrability and a high save of alkalinity which fulfills both the physical needs and substance necessities of the solid spread. If the solid is porous to environmental gasses or incline in concrete, erosion of the support can be expected and great assurance ought to be endeavored by the utilization of thick total and an all-around compacted blend with a sensibly low water/bond proportion. If chloride erosion is acknowledged, it is presently typically concurred that carbonation of solid spread is the fundamental condition for consumption of support. As talked about in the Effects of Fly Ash on Carbonation of Concrete segment over, the issue of carbonation of fly-powder concrete has gotten some consideration as of late; in any case, it is our conviction that the carbonation of fly-ash cement is not something to worry about, if consideration is paid to acquiring sufficient impermeability in the solid mass.

1.5.9 Effects of Fly Ash on Concrete Exposed to Seawater

Presentation of cement to the marine environment subjects it to a variety of extremely forceful variables, including the greater part of those talked about in the former areas of this section. Concrete in tidal zones is the most seriously assaulted, exposed as it is to exchanging wetting and drying, wave activity, scraped spot by sand and flotsam and jetsam, continuous solidifying and defrosting cycles, and erosion of support—all happening in an artificially forceful medium. For all time inundated cement is less extremely influenced. Next to no immediate perception of fly-fiery remains concrete in seawater has been accounted for in the writing, albeit some examination around there has been accounted at [Malhotra *et al*., (1980)].

[Malhotra *et al.,* (1988), (1992)**]** started a long haul venture on marine-environment execution of cements consolidating supplementary establishing materials. Test examples were presented to rehashed cycles of wetting and going and away to roughly 100 solidifying and defrosting cycles every year. Indeed, even under presentation to extreme marine conditions, cements fusing 25% fly fiery remains from a bituminous source were in acceptable condition following 15 years. The main exemptions were the examples with a water/concrete + fly ash proportion of 0.60. It was presumed that fly-slag concrete at a 25% bond substitution level (by mass) can be acceptable under such states of presentation, gave the water/cementitious materials proportion is ≤50. Though penetrability is thought to be the main consideration influencing the sturdiness of cement in seawater, it is apparent that fly fiery remains can possibly add to various parts of solid solidness in the marine environment. It is clear additionally this is a region of fly-fiery remains solid conduct that extraordinarily needs research.

[Feng *et al.,* (2011)] have made a study where it is extended the importance to study different fly ashes and to see the difference between them in concrete. They have made a study based on 43 different fly ashes and also the active strength index and major chemical properties. According to ASTM Standard C 311 and ASTM standard C 618 it is studied a finesse and acidic oxide, calcium and carbon content and there are tested many samples on 7 and 28 day strength. The main material that they use is C class and F class of fly ash and the other materials are sand, water and Portland cement. The general beneficial of fly ash in concrete is to reduce the water requirement in cement and the fly ash should be coarse material >45 micro sieve ash. A compressive study by this paper is to loss an ignition (LOI) pronouncing the effect on water requirement. According to the ASTM there should be 6 samples but because of the fineness of the fly ash they did only 5 samples because the others passed the fineness requirement. The tests were accomplished in 1, 3, 7 and 28 days and the time of setting was 140 minutes whereas the final set was in 210 minutes. In conclusion the results of all tests there were about 90% of the fly ash material tested and also this tested material can reduce the water requirement for mortar mixtures.

[Dr Pati *et al.,*] have demonstrated the importance of studying and investigating the utilization of fly ash as a partial replacement of cement and as an additive to provide an environmentally consistent way of its disposal and reuse. Their study shows the replacement in percentage of cement in concrete matrix from 5% to 25%. It is observed that replacement of cement in any proportion lowers the compressive strength of concrete as well as delays its hardening. In this experimental investigation, they have made an attempt to study the techno-economic analysis for the compressive strength of fly ash concrete. Fly ash is used in various proportions ranging from 10% to 50% by weight of cement in steps of 5% to each sample. Using the experimental data, a column section designed and the relative cost of column section designed with OPC as well as various proportion of fly ash is estimated and compared. The materials they have used are fly ash cement, sand and water. The fly ash is mixed with cement, sand and water in steps 10 % to 50% with following steps of ASTM C 618. They did 6 samples and they made test of the samples in 7 days and 28 days. Fly ash is added in different percentage by mixing with other materials. Also they made 6 samples test with Portland cement by mixing sand and water together. Fly ash is actually a solid waste so it is priceless and if it can be used for any purpose and it will be good for both environment and economy. The use of this fly ash as a raw material in Portland cement is an effective means for its management and leads to the save of cement and economy on sequent. Hence it is a safe and environmentally consistent method of disposal of fly ash. It can be concluded that power plant waste is extensively used in concrete as a partial replacement for cement and an admixture material in concrete.

[Christy *et al.,* (2010)] have experimented on four sets of mixture proportions. Firstly there was the control mix without fly ash and the other mixes contained Class F fly ash obtained in the local area. In the first three sets of proportions the mortars were prepared with 1:3, 1:4.5, and 1:6 binders to sand ratio. The fly ash was blended with the mixed cement replacement ratios of 100:0, 90:10, 80:20, 75:25, and 70:30, were investigated to obtain substitutes for the cement in the mortar. In the fourth set they used the cement mortar of ratio 1:6 where the fine aggregate was replaced with fly ash in 0%, 10%, and 20% and the obtained results were obtained with the results taken from the first three proportions of mortar. After the tests were finished and the results were obtained in the end it was achieved that incorporation of a Class – F fly ash in mixed cement is feasible for making masonry mortars in brick joints. Adequate strength development was obtained from the mortars mixes in the ratios of 1:2, 1:4.5, and 1:6. It can be used in masonry to improve the long term bond strength.

[Jain *et al.,* (2013)] have made a study on mortar containing fly ash as a partial replacement of sand by weight as well as by volume. Both the types of pond and bottom fly ash in various ratios were used in preparing cement mortar and their strengths in compression and tension were tested. The maximum utilization of fly ash almost 75% and cost saving about 58% were ascertained with the plain mortar of ratio 1:5 (cement: sand). They made the study took in the state of India which has a fly ash production of 180 million tons in the year 2010. On rigorous analysis, they have observed that the method of volume is suited better than the method of weight. Similarly, the inclusion of pond fly ash in mortar gives better results than bottom fly ash. Also they observed that the mortar of the ratio 1:1:5 (cement: fly ash :sand) when the replacement of cement is made by fly ash gives lesser strength in comparison to the replacement of sand by fly ash and the consumption of fly ash is also reduced appreciably. After the results were obtained from the study in the end it was achieved that “the various proportions under study the mortar mix containing 1:2.5:2.5 (cement: coarse sand: pond fly ash) by method of volume was observed to satisfy the strength criteria very well whereas the same ratio when considered by the method of weight is found to be most economical.

According to the Indian Standard Specification [IS:8112, (1989)] an experimental investigation was carried out to evaluate the mechanical properties of concrete mixtures in which fine aggregate (sand) was partially replaced with Class F fly ash. Fine aggregate (sand) was replaced with five percentages to each sample (10%, 20%, 30%, 40%, and 50%) of Class F fly ash by weight. The tests were performed for properties of fresh concrete. Compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity were determined at 7, 14, 28, 56, 91, and 365 days. Test results indicate significant improvement in the strength properties of plain concrete by the inclusion of fly ash as partial replacement of fine aggregate (sand) and it can be effectively used in structural concrete and the materials that were used are those of Portland cement of grade 43. The other was the fly ash which was taken in the local area according to the ASTM C 311 with its chemical composition of SiO_2 of 55.3%, Al_2O_3 25.70%, and Fe_2O_3 with 5.3 % where the ASTM C 618 requirements for this three chemical compounds it is min 70%. The fine aggregates that were used were also collected in the local area and were with a maximum size of 4.75 mm, and were tested according to the Indian Standard Specifications [IS:383, (1970)] with its physical and mechanical properties. The coarse aggregates used were also collected in the local area and has a maximum size of 20 mm which were tested and a commercial super-plasticizer was used in all mixes. There were made six mix proportions, where the first was control mix (without fly ash), and the other five mixes contained Class F fly ash. Fine aggregate (sand) was replaced with fly ash by weight. The proportions of fine aggregate replaced ranged from 10% to 50%. The control mix without fly ash was proportioned as per Indian Standard Specifications (IS:10262, 1982) to obtain a 28-day cube compressive strength of 26.4 MPa.

[Siddique, (2003)] presented concrete mixes which were made in power-driven revolving type drum mixers of capacity 0.76 m3. There were used 150-mm concrete cubes were cast for compressive strength, 150*300 mm cylinders for splitting tensile strength, 101.4* 101.4* 508 mm beams for flexural strength, and 150*300 mm cylinders for modulus of elasticity. After casting, all the test specimens were finished with a steel towel. Immediately after finishing, the specimens were covered with plastic sheets to minimize the moisture loss from them. All the test specimens were stored at temperature of about 23^0C in the casting room. They were de-molded after 24 h and were put into a water-curing tank. After the results of the study it was achieved that “compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity of fine aggregate (sand) replaced fly ash concrete specimens were higher than the plain concrete (control mix) specimens at all the ages.. Results of this investigation suggest that Class F fly ash it is very conveniently used in structural concrete. According to ASTM standard (ASTM

C78/C78M-10) there must be made many studies to see the compressive strength of concrete using fly ash and partial replacement of cement for three grades. So the effect on flexural strength of concrete at age 28 days and 90 days using fly ash in varying percentages as a partial replacement of cement for three grades of high strength concrete.

[Pitroda, (2012)] investigated the partial replacement of cement with fly ash in concrete mix design and the fresh and hardened state of it. He showed the replacement cement and fly ash according to range 0 %without fly ash and 10% 20% 30% 40% by weight of cement for M25 and M40 mix. The materials that he used to this experiment were water, fine aggregate, coarse aggregate, Portland cement with 53 grades and fly ash. All materials were mixed together according to the ASTM 618 standard. The Portland cement 53 grade was using according to IS: 8112-1989 standard. The mix M25 and M40 grade was design as per IS 10262:2009 and the same was used to prepare the tests samples which are as ASTM 618 standard. Water cement ration used was 0.40 for M20 and M40 concrete. The samples test was done in 6 cubic samples and the cubic parameters are 15x15x15cm. The samples are curing in 7days 28days and 56days strength was taken. The tests were performed on compressive test and the split compressing strength. The results of the test in 7 days 28 days and 56 days for M20 and M40 on compressive strength and split strength was to replace the cement with fly ash and to decrease due to reduction of cement. Based on results and the investigation of experiment the uses of fly ash in concrete can save the coal and thermal industry disposal costs and produce a ‘greener’ concrete for construction. In analyses of results tests indicates that percent cement reduction decreases cost of concrete, but at the same time strength also decreases. This research concludes that fly ash can be innovative supplementary cementitious Construction Material but the decisions are to be taken by engineers.

[Kumar *et al.*,(2014)**]** attempted to find a suitable utilization for a particular fly ash depending upon its properties and thus reduce the need for waste areas for disposal of fly ash which in turn causes considerable damage to the environment? Concrete is being widely used for the construction of most of the buildings, bridges, etc. Throughout the world hence it is the backbone to the infra structure development of a nation. India is taking major initiatives to improve and develop its infrastructure by constructing express highways, power projects and industrial structures. A huge quantity of concrete is required to meet the infrastructure development. Fly ash is a by-product of burned coal from power station. Considerable efforts are being taken worldwide to utilize natural waste.

[Naganathan *et al.,* (2013)] investigate the effect of fineness of fly ash on the performance of cement mortar. Fly ash from thermal plant is used as partial substitute for cement and as received and also processed by grinding. Mortar cubes are tested for strength, water absorption and sorption. Water absorption and sorption show a decreasing trend with the increase of fly ash fineness; whereas the strength increases with the increase of fineness. It is concluded that increasing the fineness of fly ash increases the strength and reduces absorption by 15% and hence is an effective method to improve its performance in cement mortar.

[M Islam *et al.,*(2010)] shows the results of an experimental investigation carried out to study the effects of fly ash on strength development of mortar and the optimum use of fly ash in mortar. Cement was partially replaced with six percentages (10%, 20%, 30%, 40%, 50% and 60%) of class F fly ash by weight. Ordinary Portland cement (OPC) mortar was also prepared as reference mortar. Compressive as well as tensile strengths of the mortar specimens were determined at 3, 7, 14, 28, 60 and 90 days. Test results show that strength increases with the increase of fly ash up to an optimum value, beyond which, strength values start decreasing with further addition of fly ash. Among the six fly ash mortars, the optimum amount of cement replacement in mortar is about 40%, which provides 14% higher compressive strength and 8% higher tensile strength as compared to OPC mortar.

[Yijin *et al.,*] has studied the examined and the addition of ultra-fine fly ash (UFA) to cement paste, mortar and concrete can improve their fluidity, but some coarse fly ash can’t reduce water. The paper is investigating the effect of fineness and replacement levels of fly ash on the fluidity of cement paste, mortar, and concrete. The fly ash is collected by electro-static precipitators and airflow classing technology.3 different fineness was chosen, and their replacement levels were 20%, 30%, and 40%, respectively. The experiment results show that particle size distribution, Zeta potential, density and particle morphologies of fly ash are the major factors affecting their fluidity.

[Bijen (1996)] has studied the fly ash advantages and disadvantages in its use. Nowadays the use of fly ash in concrete as a main or as an additional component is very widespread. Fly ash and slag have great effects on making reinforce concrete structures. One important effect is the major reduction of the rate of permeation of chloride ions into concrete and the rise of chloride concentration. Also the pore size distribution of concrete with granulated slag or fly ash is finer than Portland cement.so the main effect of fly ash and slag on the pore structure is reflected in the diffusivity of ions. Another important effect is that concretes made with fly ash or slag has a greater resistance to chemical attack than concretes made with other components. There are also disadvantages like curing sensitivity but these can be condensed if there are enough information and knowledge on concrete technology.

[Hemmings *et al.,* (1995)] present a history of the use of blended cement and their production in North America. The production and importation of cement and other components has started many years ago. Canada and USA are two important countries where fly ash is available in large amount but only 10% of it is used in concrete as replacement for cement. Also granulated blast furnace slags as well as silica fume are available but only in some regions. Despite the standards the production of blended cement in North America is not very high. The concrete industry in North America has had a rise in using the supplementary cementing materials for many important purposes.

[Sun *et al.,* (2013)] made a study on freeze thaw resistance of fly ash using these materials: class F fly ash, silica fume, metakaolin, sodium hydroxide, sodium sulfate, sulfuric acid and fine sand. Examples of various compositions were experimented to standard freeze–thaw immersed in 5% sodium sulfate solution, 3% sulfuric acid solution, and 0.05% sulfuric acid solution, respectively, for 24 weeks. The results of the study were as: FA specimens showed no deterioration in 5% Na2SO4 solutions up to 24 weeks. All the FA specimens showed continuous increases in mass and compressive strength with time; the resistance of FA mortars to 5% Na2SO4 solutions was better than OPC, at least for the time period (24 weeks) investigated in this study; FA mortars deteriorated in strong H2SO4 solutions. The higher was the concentration, the faster was the deterioration rate.

CHAPTER 2

MATERIALS AND METHODS

In materials part of this chapter the properties of the materials used for the production of the mortars used in this study. In the method part of the chapter the experimental design and laboratory tests have been explained. The materials used are: sand, water, Portland Cement 52.5 R and fly ash. This chapter includes also the physical and chemical properties of the materials.

2.1 Sand

The crushed limestone sand used in this experimental work was taken from Fushe-Kruja, Albania. It had a specific gravity of 2.56 and a maximum aggregate size of 4mm. The *(Table 8)* shows the grading of sand that is used in the experiment.

Figure 10. The crushed limestone sand

Table 8. Grading sand by sieves

Sieve size	4	2	1	0.5	0.25	0.125	0.063	pan
cumulative % retained	0	16.5	53.8	71.4	83.9	92.6	98.8	100

2.1.2 Water

It is important to know the water that is going to be used in mortar mixtures. According to experiments done many years ago until now, based on many books related to concrete and based on standard [EN 1008, (2003**)]** there are defined some rules concerning suitable water for concrete mixture and also determining if the water is potable and if so, how suitable can it be in production of concrete mortars. All urban waters cannot be similar with each other in quality. Foreign contents that are found in water are not in that large amount so that the concrete could be damaged. That is why in the production of concrete, washing water and healing water are obtained from the drinking water that comes from the water supply network of the town or village of the area. In this study tap water of Epoka University Campus is used for the production of the mortar mixtures.

2.1.3 Cement CEM 1 52.5 R

The cement used in this experimental work is CEM I 52.5 R produced by Heracles ™ Company in Greece. It complies with the requirements of [ELOT EN 197-1] and it is cement certified by an independent body and carries a CE Mark Heracles ™. The **c**ement used in this work is white cement 52.5 R which can be used for plaster as well as for concrete applications. This cement was brought from Greece purposely for this study, because in the Albanian construction market there is no Ordinary Portland Cement.

Figure 11. White Heracles cement CEM I 52.5

Table 9. The chemical characteristics of CEM I 52

Chemical Properties	**As Cement Declaration**	**Standard**	**Unit**
SiO_2	20,09		%
Fe_2O_3	3,87		%
Al_2O_3	4,84		%
CaO	64,02		%
MgO	1,15	Max 5,0	%
SO3	2,83	Max 4,0	%
Loss On Ignition	2,36	Max 5,0	%
Insoluble Residue	0,34	Max 5,0	%
Free Lime	0,80		%
Alkali Equivalent (Na2O type)	0,65		%
Total Additive	3,85		%

Table. 2.3

Table 10. The Physical characteristics of CEM I 52, R

Physical Properties	As Cement Declaration	Standard	Unit
Setting Time (Initial)	165	Min 45	%
Setting Time (Final)	275	-	%
Specific Gravity	3,156	-	%
Expansion	1,00	Max 10	%
Strength for 2 days	31,10	Min 30	%
Strength for 28 days	56,40	Min 52,5	%

2.1.4 Fly ash FA

Fly ash produced in the thermal power plant built in the village of Obiliq in Pristine, Kosovo was used in this study. The fly ash is class C which has the high calcium (CaO) content with SiO_2 + Al_2O_3 + $Fe_2O_3 \geq 50\%$. The Chemical analyzes were made by ("KEK"), which is the Electro-Energy Corporate of Kosovo. In Table 2.4 and Table 2.3 are given the mineral and chemical composition of fly ash. This Fly ash is a waste material which is thrown in field areas and partially used by (TITAN) cement in Kosovo and some other local companies as a chemical admixture in blended Portland cement.

Figure 12. Fly ash of Kosovo

Table 11.The mineral composition of Fly ash

Mineral composition	Participation
Calcium sulfate ($CaSO_4$)	38
CaO	31
Portland $Ca(OH)_2$	2
Gehlenit ($Ca_2 Al_2 SiO_7$)	12
Magnesium oxide (MgO)	2
Calcium carbonate ($CaCO_3$)	15
Silica (SiO_2)	5
Iron Oxide (FeO,OH)	2
$Ca,Al_{2,}Si_2O_8$ +,H_2O	3

2.1.5 The Density and bulk density and hydraulic compaction

Density 2400 kg/m3

Bulk density 626.9 kg/m3

Mass density 941.5 kg/m3

For the process of solidification, it is necessary to provide a corresponding stoichiometric ratio of solid and liquid phases. During obscene laboratory tests, with the industrial and waste water power plants, came down to a ratio of a wider range of solid and liquid phases that meets the requirements in terms of speed fully cured technological water and hardening mass. This ratio ranges from 40 - 60% solid phase, i.e. ash, by weight. For participation in the ash amount of 60% of the process is accomplished within one day, or up to five days when it comes to the participation of the ashes of 40%. In the course of industrial hydraulic tests deposit of ash, the process is conducted with a slurry density between 47 and 51% C, and at the same time was obtained satisfactory results in terms of flow and intensity of the solidification process. On the basis of all examinations carried out, passed the weight ratio of the ashes in water of 45 - 55% solid, as the most favorable.

2.1.6 Chemical composition of Fly ash

Table 12. Fly ash components analysis

Components	Sample 1 in (%)	Sample 2 in (%)
CaO	35.38-39.96	28.30-34.76
SiO_2	29.50-32.13	27.58-33.12
Al_2O_3	5.09-6.46	8.55-10.53
Fe_2O_3	6.31-8.42	6.03-7.95
MgO	3.55-4.02	3.37-4.01
SO_3	11.02-12.78	11.17-12.89
MnO	0.18-0.32	0.14-0.17
K_2O	0.45-0.56	0.79-1.01
Na_2O	1.52-1.71	1.06-1.70
CaO	7.34-9.42	4.95-6.84

In (*Table 12)* is showing the chemical composition of fly ah samples as it is seen in the tables the sample one has more amount of CaO, SiO_2, Al_2O_3, Fe_2O_3, MgO, MnO, Na_2O, CaO so in sample one the has done the tests in 45 days and the sample two is done in 120 days and it has K_2O, SO_3, a little more than sample one but the difference are too small in numbers.

In (*Table 12)* is showing the mineral composition of ash participation and the amount of the materials in numbers. As is showing in the figure mostly has Calcium sulfate ($CaSO_4$) and CaO which are the materials that help in good binding in concrete chemical material. So as is seeing in result analysis the fly ash is very good material to produce the mortar or concrete with fly ash mineral admixtures.

2.2 Methodology

2.2.1 Defining the Normal consistency, initial and final setting time

The Normal consistency, initial and final setting time have been defined based on EN 196-3 standard. According to this procedure we first take 500 g of cement and place it in the enameled tray, after that about 25% water by weight of dry cement thoroughly is added to cement to get a cement paste. After preparing the mix the vicat mold, resting upon a glass plate, is filled with this cement paste. After filling the mould completely, the surface of the paste is smoothed, making it leveled with top of the mold. The whole equipment (i.e. mould + cement paste + glass plate) is placed under the rod bearing plunger. The plunger is lowered gently so as to touch the surface of the test block and quickly released allowing it to sink into the paste. Then the depth of penetration is measured and recorded. Trial pastes with varying percentages of water content are prepared following the steps described above, until the depth of penetration becomes 6±1mm from the bottom of the mold. Then the ratio of water to cement used for mix that reached the normal consistency is calculated.

Figure 13. The Normal consistency by vicat apparatus

For the calculation of the initial setting time the test sample confined in the mold and resting on the non-porous plate is placed under the rod bearing the needle. The needle is lowered gently until it comes in contact with the surface of test block and quickly released, allowing it to penetrate into the test sample. In the beginning the needle completely pierces the sample. The procedure is repeated after every 2 minutes till the needle fails to pierce the block for about 4±1mm measured from the bottom of the mold. The time passed from the preparation of the sample up to this moment is the initial setting time.

Figure 14. Vicat apparatus finding Normal consistency, initial and final setting time

For the calculation of the final setting time the test sample confined in the mold and resting on the non-porous plate is placed under the rod bearing the needle with an annular attachment. The needle is lowered gently until it comes to the surface of the sample; the needle makes an impression thereon until the attachment fails to do so. The procedure is repeated after every 30 minutes. The time passed from the preparation of the sample up to this moment is the final setting time.

2.2.2 Sieve analysis of the crushed limestone sand.

The sand sieve analysis is carried out as often as is required to maintain the correct grading of sand that is to be used. The grading of a sand aggregate is determined by passing a representative sample of dry sand through a series of sieves according to EN 13139 (2002) (or local equivalent standard), starting with the largest sieve.

Figure 15. The crushed limestone

If the sieving is done manually, each sieve is shaken separately over a clean tray for not less than two minutes. If machine sieving is applied, a nest of sieves should be shaken for at least 15 minutes. The material retained on each sieve, together with any material cleaned from the mesh is weighed and recorded. The percentage by weight passing each sieve is then calculated. Sieving will not be accurate if there is too much material left on any mesh after shaking.

2.2.3. Testing of Fine Aggregates

The samples were washed through No. 200 mesh until the washing water became clear. The washed samples were placed in a pan; then water was added until it covered the surface of the aggregates completely for 24 hours. Afterword's, the samples were carefully drained in a manner to avoid loss of any fine particles. Once, the particles were saturated-surface dry (to make the samples saturated surface dry, the samples are mixed thoroughly under hair dry. The drying process was verified by cone test.), about 316 gr saturated surface dry sample was placed in a hydrometer.

Figure 16. Using hydrometer for testing surface dry sample

Then, the weight of the hydrometer and the sample were determined. Water was added to the hydrometer until the surface of the sample was fully covered. Then, hydrometer was shaking until whole air bubbles were disappeared. The sample was weighed after the hydrometer was taken off the water bath and checked for right water level. The fine aggregates were placed in a pan and dried at 105 ± 5 ºC for 24 hours. After 24 hours, the samples were left in room temperature to cool. The accuracy of weighting was 0.1 gr. The specific gravity and water absorption values were determined by ASTM C128.

Figure 17. The drying process was dried by hair drying

2.2.4 Preparation of the Specimen Mixtures

Six different series of 0.5 water to binder ratio and (0/100, 5/95,10/90,15/85.20/80 and 25/75) fly ash to cement ratios (FA/PC) were used. The results were compared with those carried out with the control specimens produced with 0, 5 w/c ratio and no other additive. All the materials used for the preparation of the specimens were weighed separately according to their rates on a precision scale. The ingredients of the mortar mixtures are given in Table 2.5. For all the mixtures, the sand weight is given in dry condition.

Table 13. Preparation of specimens

samples	sand (g)	CEM 1 52.5 R(g)	water (g)	(FA) fly ash(g)
0%	1350	450	225	0
5%	1350	427.5	225	22.5
10%	1350	405	225	45
15%	1350	382.5	225	67.5
20%	1350	360	225	90
25%	1350	337.5	225	112.5

Figure 18. Preparations of the Specimen Mixtures

Figure 19. Empty specimens

2.2.5 Casting of the Specimens

The mixes were prepared according to the mix proportions given in *(Table 13)* and mixed in the Hobart mixer in a certain order. The Hobart mixer operates in conformity to EN–196-1. The standard was performing 140 and 285 rotations/minute. The specimens were casted into prismatic molds of 40 x 40x 160 mm and tested for 28 days flexural and compressive strength.

The Hobart mixer was used in automatic adjustment according to EN 196-1 Standard. Firstly, the water and solid phase were mixed in the low gear for 30 seconds, in the second step while the mixer is still working the sand is added slowly and mixed for 30 seconds again in the low gear. Then in the third step the mixer starts turning in the high gear and continues mixing for 30 seconds. In the fourth step it stops for 15 seconds. After that, it goes for 60 seconds in the high gear. As the mixer stops, with an appropriate spoon the fresh mortar is put into the molds in two layers and impacted 60 times in one minute and then the mortars surface is finished. After 24 hours, the specimens are taken out of the molds and cured for 14 and 28 days in water at 21±1 ºC.

Figure 20. Manual mortar mixers

Figure 21. Mixing all materials together

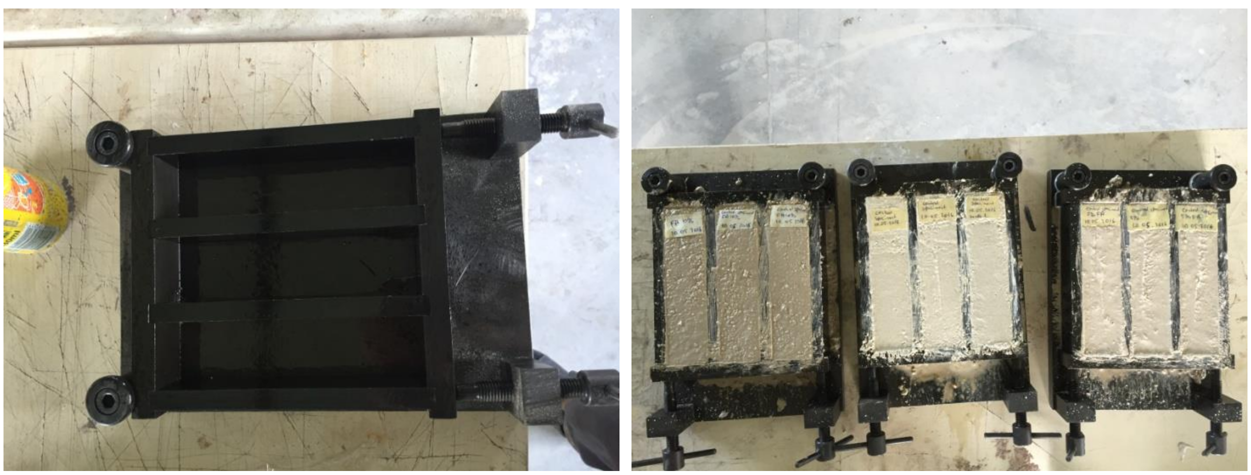


Figure 22. Casting of the Specimens

2.2.6 Determination of the Water Absorption

The water absorption was measured from 40x40x160 mm prismatic specimens immersed in water for 24 hours. The specimens were in saturated surface dry conditions (SSD) and dry weight. After taking the specimens out of water, firstly each sample was weight in saturated surface dry conditions (SSD) after this process they were placed in the oven at 105°C for 24 hours. Next day the samples were taken out of the oven and cooled up to room temperature, then weighed in dry condition. The water absorption was found as shown in the formula, where:

WA (%) = [(SSD-CD)/ (CD)] ×100

WA: The water absorption (%)

CD: The mass of the completely dried specimen (g)

SSD: The mass of the saturated surface dried specimen (g)

Figure 23. Curing of mortar specimens

2.2.7 Determination of the Flexural Strength

The flexural test of the specimens was performed according to EN 1015–11 (2007) Standard. In order to determine the flexural strength of the mortars 40x40x160 mm specimens were used. The specimens were tested for 14 and 28 days strength under three-point loading and the span between the supports is 100 mm. The tensile strength was calculated as below:

$$\sigma = 3PL/2bd^2 \quad (1)$$

Where:

σ: Flexural Strength (Newton/mm2)

B: Width of the Prisms Cross-Section (mm)

D: Height of the Prisms Cross-Section (mm)

P: Average Load That Causes the Specimen Failure (N),

L: Distance between the Supports [mm].

Figure 24. Determination of the Flexural Strength

2.2.8 The Determination of the Compressive Strength

The compressive strength test was carried out in accordance with relevant specification BS EN 196-1:2005 [EN196-1, (2009)]. The two broken parts of the 40 x 40 x 160 mm retained after the flexural strength test were used for compressive strength. The loading rate is 500 N/s. The loading area is 40 x 40 mm. The average of results obtained from six broken pieces was reported as compressive strength.

Figure 25. Determination of the Compressive Strength

2.2.9 Determination of shrinkage

It checks the length change of mortar samples from their initial measurement in different time periods after removing them from the molds. The length change evaluation of mortar samples is performed based on ASSTM C157 (2008). According to this standard the test is done on prismatic samples 25x25x285mm dimensions. From each mixture there are prepared 2 samples and the measures of contraction are taken as the average of both samples. After removing them from the molds, where the mortars are left for 24 hours, is taken the initial length of the mortars. After the first measurement the specimens are kept in room temperature conditions at 21±1 ºC and in an environment with 65% humidity. The samples have been monitored for days after being removed from the molds.

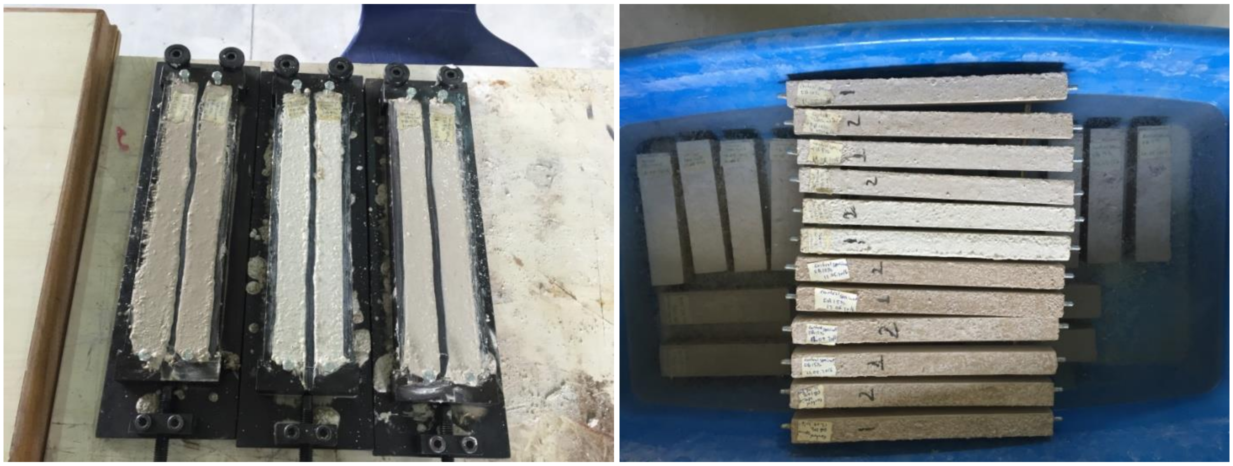


Figure 26. Shrinkage test samples

Figure 27. Curing of shrinkage samples

CHAPTER 3

RESULTS AND DISCUSSION

3.1 Defining of Normal consistency, initial and final setting time

Table 14. Preparation of specimens

samples	binder	Water	W/C	Initial setting	final setting
0%	500.00	169	0.34	55min	270min
5%	500.00	175	0.35	60min	285min
10%	500.00	181	0.36	65min	315min
15%	500.00	194	0.39	65min	330min
20%	500.00	200	0.40	70min	385min
25%	500.00	206	0.41	70min	430min

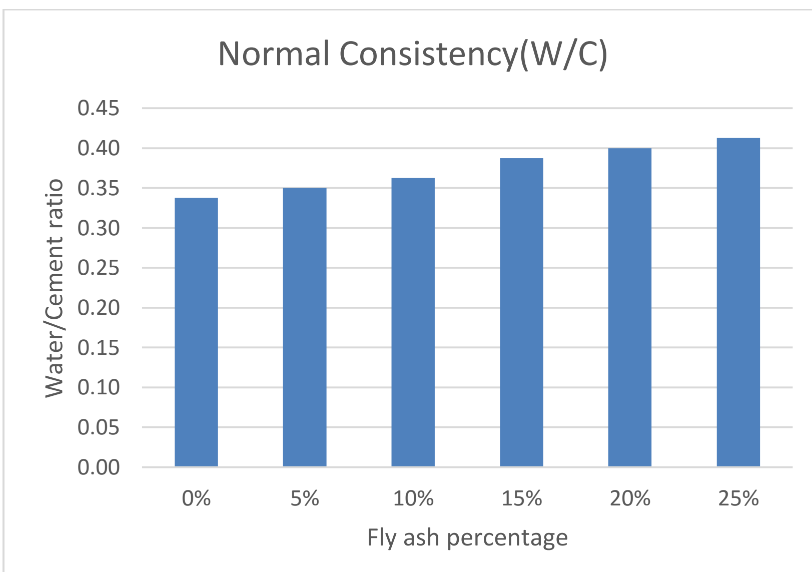


Figure 28. Normal Consistency

According to the test results of the measurement of normal consistency defined as water to binder ratio, as it can be seen in *(Table 14)* and in *(Fig 29)*. The water demand to reach to normal consistency increases as the percentage of fly ash used in the mix increases. This can be explained also with the higher fineness of the fly ash used in the study related to that of the Portland cement. The water demand increases almost linearly.

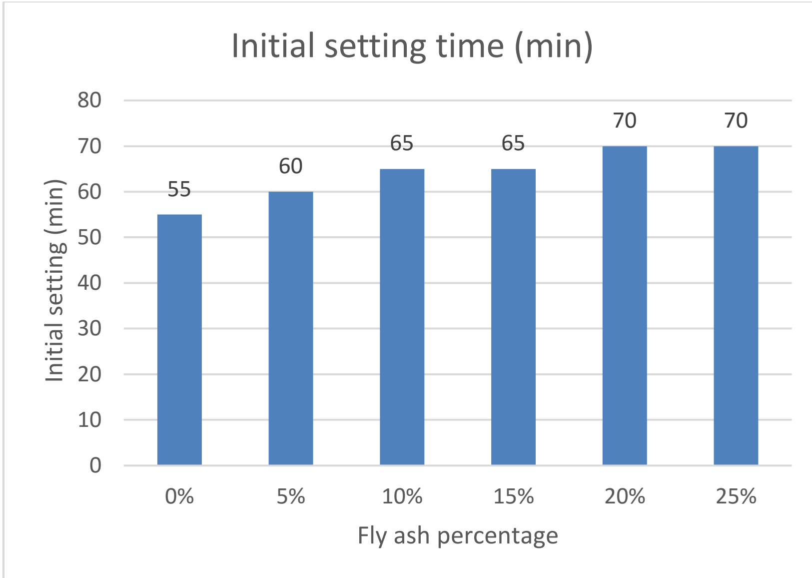


Figure 29. Initial setting time

According to the test results of the measurement of initial setting time defined as the time measured till the Vicat needle fails to pierce the block for about 4±1mm measured from the bottom of the mold., as it can be seen in *(Table 14)* and in *(Fig 29)* the initial setting time increases as the percentage of fly ash used in the mix increases. This can be explained with the pozzolanic activity of fly ash. It is well known that the pozzolanic reaction is slower than the hydration reaction of cement. In the study made by Feng and Clark the initial setting time was similar to my measurements [Feng *et al*. (2011)].

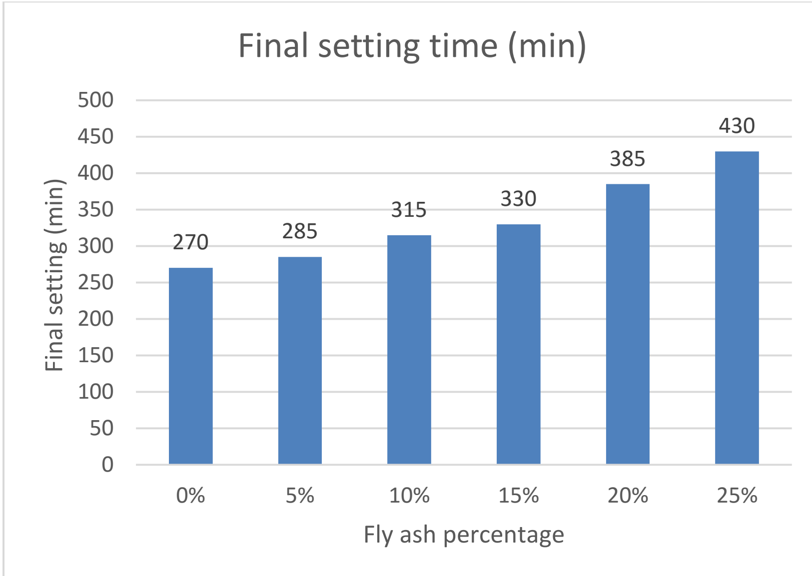


Figure 30. Final setting times

For the calculation of the final setting time the test sample confined in the mold and resting on the non-porous plate is placed under the rod bearing the needle with an annular attachment. The needle is lowered gently until it comes to the surface of the sample; the needle makes an impression thereon until the attachment fails to do so. The time passed from the preparation of the sample up to this moment is the final setting time. The test results show similar trend as the initial setting time results. The time increases as the percentage of fly ash content increases. The same logical explanation can be followed also in this case. In the study made by Feng and Clark the final setting time was similar to my measurements [Feng *et al.* (2011)].

3.2 Sieve analysis of the crushed limestone sand.

Table 15. Test of Sieve analysis of the crushed limestone sand.

Sieve Size in (mm)	Cumulative Mass Retained (g)	Adjusted Cumulative Mass Retained (g)	Cumulative Percent Retained%	Reported Percent Passing*%
4	0	0	0	100.0
2	166.5	166.5	16.5	83.4
1	372	538.5	53.8	46.2
0.5	175.5	714	71.4	28.6
0.25	125	839	83.9	16.1
0.125	87	926	92.6	7.4
0.063	62	988	98.8	1.2
Pan	12	1000	100	0.0

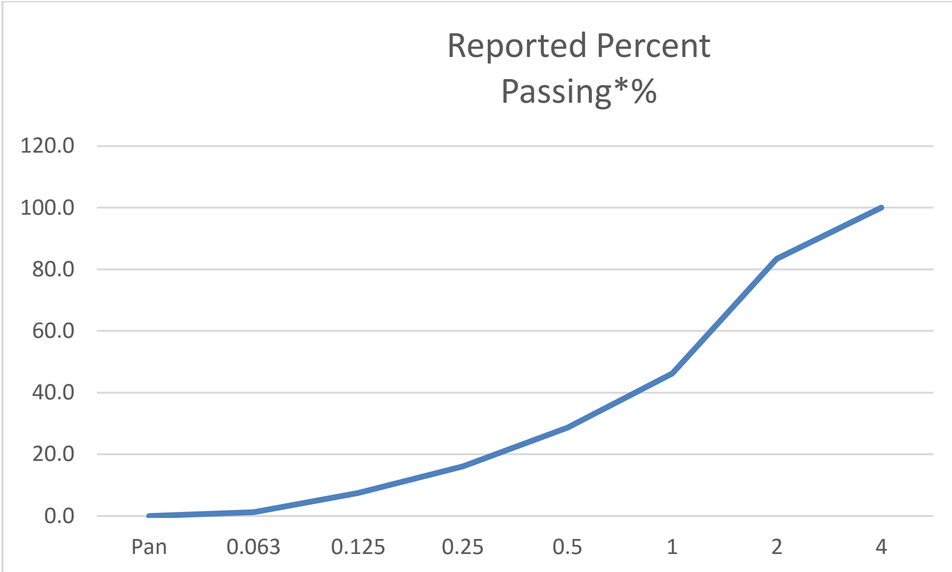


Figure 31. Results of sieve analysis of sand in percentage

After performing the sieve analysis of the crushed limestone sand the following grading was obtained. The grading percentage shows to be in compliance with the standard so that it can be used for the preparation of the mortars.

3.3 Sampling and Testing of Fine Aggregates

Table 16. Test of fine aggregates of crushed limestone sand.

A	**Weight of Empty Hydrometer**	272.5
B	**Hydrometer +SSD sample weight**	593
B+D=E	**Hydrometer +SSD sample weight + Weight of pure water**	963
F	**Empty pan**	550.5
F+G=H	**Pan + Dry sample weight**	867
K	**Weight of dry sample**	316.5
B-D=L	**SSD sample weight**	**320.5**
L-K=T	**Weight of water absorbed in SSD conditions**	**4.0**

500-(E-B)=S	**SSD the form of absolute volume of sample**	**130.0**
S-T=V	**Volume of Solid Mater**	**126.0**
K/S=M	**Specific gravity of Dry Sample**	**2.435**
L/S=N	**Specific gravity of SSD Sample**	**2.465**
K/V=Z	**Bulk Specific gravity of the Sample**	**2.512**
T/K*100	**Water absorption capacity**	**1.264**

After choosing a representative sample of the crushed limestone sand the physical properties of the sand were investigated according to ASTM D75 / D75M.The values of the test results are given at *(Table 16)* which result is showing with corresponding numbers and letters.

3.4 Determination of the Water Absorption of mortar samples

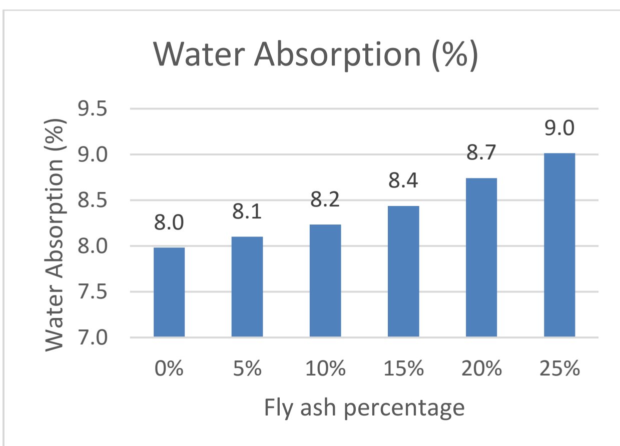


Figure 32. Determination of the Water Absorption of mortar samples in percentage

The values of the water absorption of the mortar samples show an increase in the water absorption capacity as the percentage of the Fly ash increases. The increase is linear, which shows that this value is directly proportional to the fly ash content. The lowest value is that of the control specimen prepared with 100% Portland cement which is equal to 8% whereas the highest one is that of the specimen prepared by replacing 25% of Portland cement with Fly ash equal to

9%. The change in absorption is only totally 1% or 0. 1-0.3% for every 5% of Portland cement replaced.

3.5 Determination of the Flexural Strength

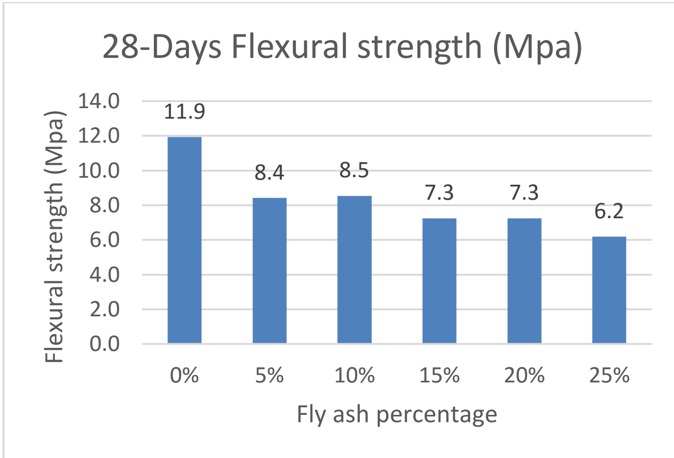


Figure 33. The evaluation of 28-days flexural strength according to fly ash percentage

The Flexural Strength of the mortar samples decreases as the percentage of the Fly ash increases. The highest value is that of the control specimen prepared with 100% Portland cement which is equal to 11.9 MPa whereas the lowest one is that of the specimen prepared by replacing 25% of Portland cement with Fly ash equal to 6.2 MPa.

3.6 The Determination of the Compressive Strength

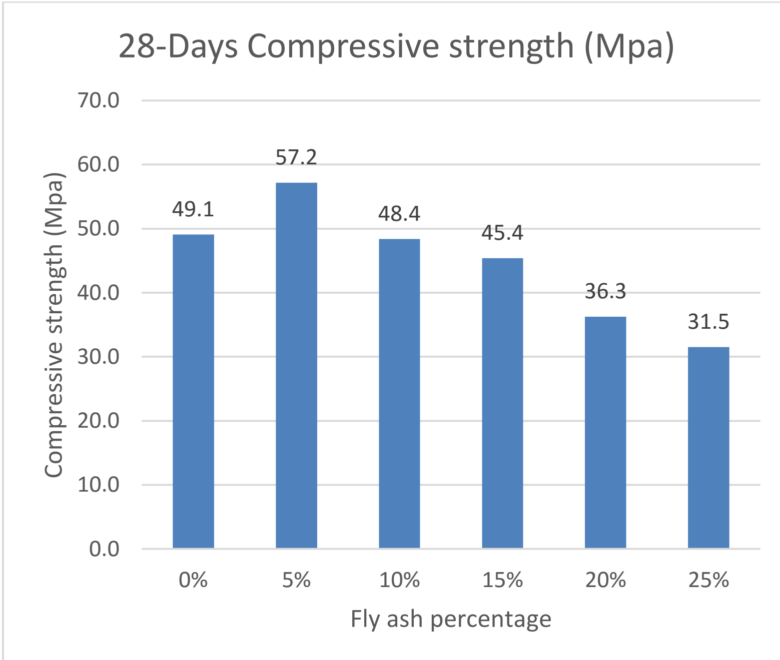


Figure 34. The evaluation of 28-days compressive strength according to fly ash percentage

The most important parameter of this study and also the most important one for the properties of cement mortars is for sure the compressive strength. In this test there were obtained very interesting results which strengthen the idea of the usability of Kosovo Fly ash in cement mortars or in concrete. As it can be distinguished from the graph the use of fly ash up to 5% increases the compressive strength more than 16%, whereas the use of fly ash up to 10% shows similar values to those of control specimens, it starts to decrease at 15% of fly ash but still with acceptable values less than 10% lower to those of control specimens. Higher fly ash content decreases considerably the compressive strength of the mortars. Similarly to these results other studies have accomplished the replacement of cement with fly ash from 10% to 15% [Christy *et al.* 2010; Naganathan *et al.* 2013; Islam *et al.* 2010; Pitroda 2012]..

3.7 Determination of shrinkage

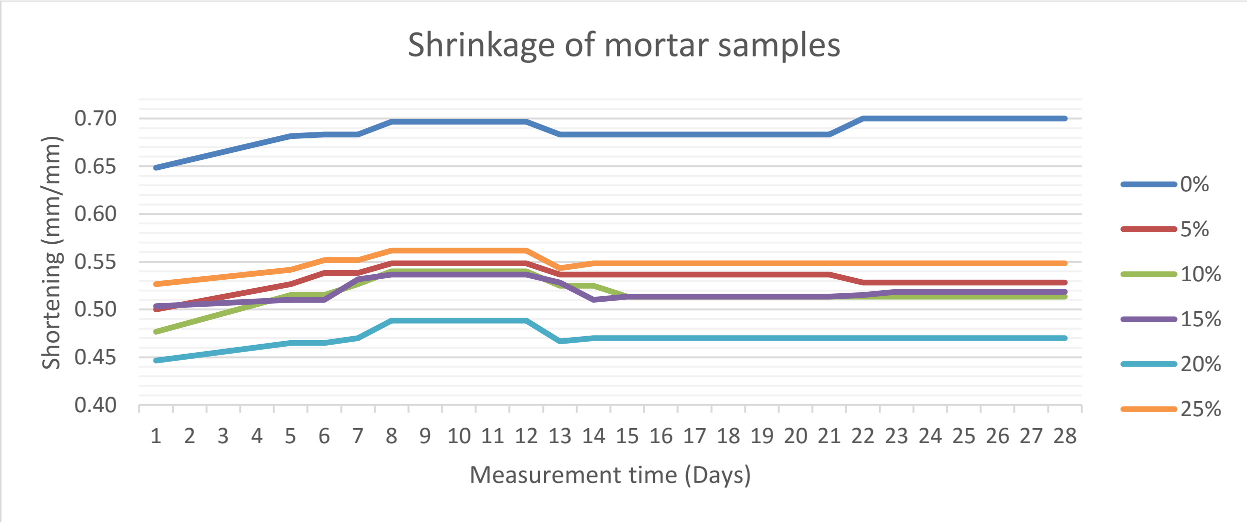


Figure 35. The evaluation of shrinkage mortar samples according to 28 days

According to the monitoring of the length change of the mortar samples for 28 days the values shown in the graph above were obtained. As it can be observed the trend of the shrinkage values of each mortar type is very similar and not distinguishable shrinkage is measured. This shows that the replacement of Portland cement with Kosovo fly ash up to 25% does not have any effect on the shrinkage of the cement mortars or concrete.

CHAPTER 4

CONCLUSION

In this experimental study the partial replacement of Kosovo fly ash in cement mortar has been investigated and the results were compared with those carried out with the control specimens produced with 0,5 w/c ratio and no other additive.
The results of initial setting time and final setting time of fly ash mortars increases as the percentage of fly ash used in the mix increases. This can be explained with the pozzolanic activity of fly ash. It is well known that the pozzolanic reaction is slower than the hydration reaction of cement.

The water absorption of control specimen prepared with 100% Portland cement is the lowest one which is equal to 8% whereas the highest one is that of the specimen prepared by replacing 25% of Portland cement with Fly ash equal to 9%. The change in absorption is only totally 1% or 0. 1-0.3% for every 5% of Portland cement replaced

The results of flexural Strength of the mortar samples decrease as the percentage of the Fly ash increases. The highest value is that of the control specimen prepared with 100% Portland cement which is equal to 11.9 MPa whereas the lowest one is that of the specimen prepared by replacing 25% of Portland cement with Fly ash equal to 6.2 MPa so based on results the flexural Strength it can be used 0% to 10% of fly ash mortars.
The shrinkage tests and the values of each mortars type are very similar and not distinguishable shrinkage is measured. This shows that the replacement of Portland cement with Kosovo fly ash up to 25% does not have any effect on the shrinkage of the cement mortars or concrete.

Test results show that Kosovo fly ash has good parameters that improve the Compressive strength of cement mortars and concrete by replacing the Portland cement up to 10%. On the other it might affect slightly the water absorption capacity of the mortars. Nevertheless, it can be concluded that the use of Kosovo fly ash in concrete could be a good alternative to be used as a pozzolanic material.

REFERENCES

AASHTO M 295, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete, American Association of State Highway and Transportation Officials, Washington, DC, 2007.

ASTM C 311-94a,"Standart Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for use as mineral admixture in Portland cement,"1994 Annual book of ASTM Standards.

ASTM C78/C78M-10. (n.d.). Standard Test Method for Flexural Strength of Concrete.
ASTMC618. (n.d.). ASTM C61 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use on Concrete. AASHTO M 295.

Bijen, J., Benefits of slag and fly ash. Great Britain: Elsevier Science (1996).

Carrasquillo P., Durability of concrete containing fly ash for use in highway applications. In J. M. Scanlon (Ed.), Concrete Durability: Katherine and Bryant Mather International Conference. 1, pp. 843-861. Farmington Hills MI: American Concrete Institute (1987).

Christy CF., Tensing D., Effect of Class-F fly ash as partial replacement with cement and aggregate in mortar, Indian Journal of Engineering and Materials Sciences, 17, 140-144 (2010).

Davis RE. Pozzolanic Materials with Special Reference to Their Use in Concrete Pipe. Irving TX: American Concrete Ppipe Association (1954).

Dr Pati SL., Kale JN., Suman S. (n.d.). Fly Ash concrete: A Technical Analysis for Compressive Strength. International Journal of Advanced Engineering Research and Studies.

Erdogan TY., Admixtures for concrete. Ankara: Middle East Technical University (1997).

Feng X., Clark B., Evaluation of the Physical and Chemical Properties of Fly Ash Products for Use in Portland cement. World of Coal Ash (WOCA) Conference. USA (2011).

Gebler S., Klieger P., Effect of fly ash on physical properties of concrete. In V. M. Malhotra (Ed.), Proceedings of the 2nd International Conference on the Use of Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete. 2. Farmington Hills: American Concrete Institute (1986).

Ghosh RS., Timusk J., Creep of fly ash concrete. In Concrete Construction Engineering Handbook (1981).

IS: 10262. Recommended Guidelines for Concrete Mix Design. New Delhi India: Bureau of Indian Standards (1982).

IS: 383. Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete. New Delhi India: Bureau of Indian Standards (1970).

IS: 8112. Specifications for 43-Grade Portland Cement. New Delhi India: Bureau of Indian Standards (1989).

Islam MM. Islam MS., Strength Behavior of Mortar Using Fly Ash as Partial Replacement of Cement. Concrete Research Letters, 1(3) (2010).

Jain A., Islam N., Use of Fly Ash as Partial Replacement of Sand in Cement Mortar. International Journal of Innovative Research in Science, Engineering and Technology, 2(5) (2013).

www.kek-energy.com (lastly visited on 10 June 2016)

Krasniqi D., Latifi M., Teknika e tensioneve te larta. Prishtine (1996).

Kumar SA., Kumar SA., R AT., Effect of Fly Ash as a Cement Replacement on the Strength of Concrete. International Journal of Engineering and Advanced Technology, 4(2) (2014).

Malhotra VM., Hemmings RT., Blended cements in North America. Great Britain: Elsevier Science (1995).

Malhotra VM., Carette GG., Bremner TW., Durability of Concrete Containing Granualted Blast Furnace Slag or Fly Ash or Both in Marine Environments. Ottawa: Canada Center for Mineral and Energy Technology (CANMET) (1980).

Malhotra VM., Carette GG., Bremner TW., Current status of CANMET's studies on the durability of concrete containing supplementary cementing materials in marine environments. Proceedings of the 2nd CANMET/ACI International Conference on Concrete in Marine Environment. Farmington Hills MI: American Concrete Institute (1988).

Malhotra VM., Carette GG., Bremner TW., CANMET Investigations Dealing with the Performance of Concrete Containing Supplementary Cementing Materials at Treat Island, Maine. Ottawa: Canada Center for Mineral and Energy Technology (CANMET) (1992).

Naganathan S., Linda T., Effect of Fly Ash Fineness on the Performance of Cement Mortar. Jordan Journal of Civil Engineering, 7(3) (2013).

Naik TR., Ramme, BW., Low Cement Content High Strength Concrete (Vol. 17). Cement and Concrete Research (1987).

Naik TR., Singh SA., Hossein MM., Abrasion Resistance of High Volume Fly Ash Concrete Systems. Pablo Alto CA: Electric Power Research Institute (1992).

Pitroda J., Experimental Investigations on Partial Replacement of Cement with Fly Ash in Design Mix Concrete. Intenational Journal of Advanced Engineering Technology (2012).

Puertas F., Alkali activated fly ash/slag cement Strength behavior and hydration products. (2000).

Short N.R., Page CL., The diffusion of chloride ions through Portland and blended cement pastes (1982).

Siddique R., Effect of fine aggregate replacement with Class F fly ash on the mechanical properties of concrete. Cement and Concrete Research, 33, pp. 539-547 (2003).

Stanton TE., Expansion of concrete through reaction between cement and aggregate (1940).

Sun P., Wu HC., Chemical and freeze-thaw resistance of fly ash-based inorganic mortars. Detroit USA: Elsevier (2013).

Swenson EG., Gillott JE., Characteristics of Kingston Carbonate Rock Reaction. Washington D.C: Highway Research Board (1960).

Technical Committee on Corrosion of Steel in Concrete. The Reunion Internationale des Laboratoires D'Essais et de Recherches sur les Materiaux et les Constructions (RILEM) (1974).

Thomas M., Optimizing the Use of Fly Ash in Concrete. USA: Portland Cement Association (2007).

EN.1015–11., Mortar Testing Method, Part 11. Measurement of Compressive and Flexural Tensile Strength of Mortar. Ankara: TSE (2000).

EN196-1., Methods of Testing Cement – Part 1: Strength Determination. European Standards Institution (2009).

Wesche K., Fly Ash in Concrete Properties and Performance. E&FN SPON (1991).

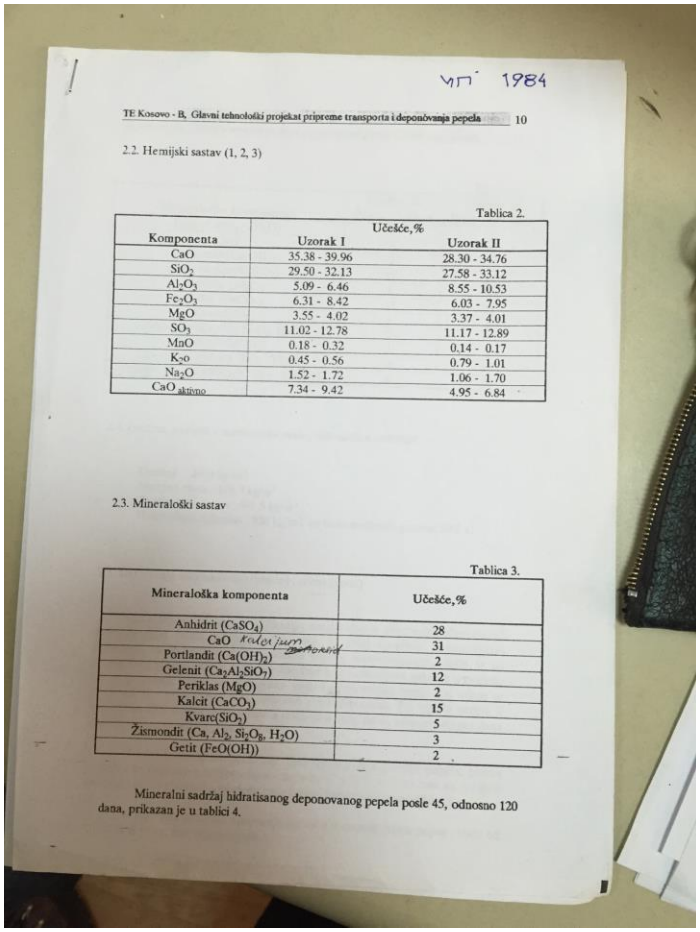
Williams JT., Owens PL., The implications of a selected grade of United Kingdom pulverized fuel ash on the engineering design and use in structural concrete. In J. G. Cabrera, & A. R. Cusens (Ed.), Proceedings of International Symposium on the Use of PFA in concrete (pp. 301-313). UK: Department of Civil Engineering University of Leeds (1982).

Yijin L., Shiqiong Z., Jian Y., Yingli G. (n.d.). TheEffect of Fly Ash on the Fluidity of Cement Paste, Mortar, and Concrete.

Yuan RL., Cook JE., Study of a Class C fly ash concrete in Fly Ash, Silica Fume, Slag and Other Mineral Byproducts in Concrete. Farmington Hills: American Concrete Institute (1983).

Zhao FQ., Activated fly ash/slag blended cement . Resources Conservation and Research (2007).

APPENDIX A



TE Kosovo - B, Glavni tehnološki projekat pripreme transporta i deponovanja pepela 10

2.2. Hemijski sastav (1, 2, 3)

Tablica 2.

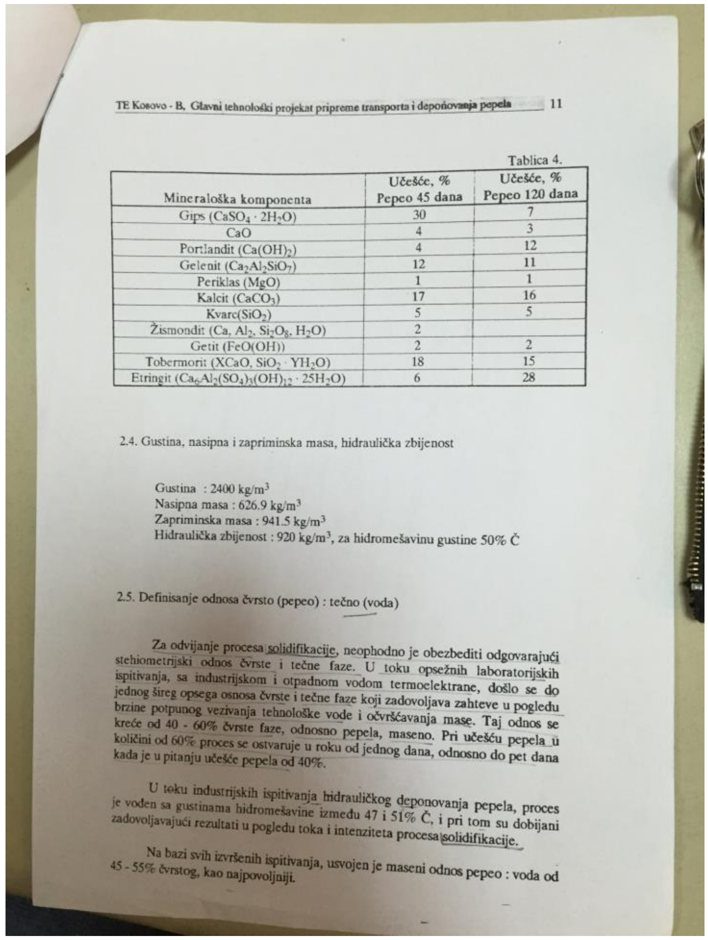
Komponenta	Učešće,%	
	Uzorak I	Uzorak II
CaO	35.38 - 39.96	28.30 - 34.76
SiO_2	29.50 - 32.13	27.58 - 33.12
Al_2O_3	5.09 - 6.46	8.55 - 10.53
Fe_2O_3	6.31 - 8.42	6.03 - 7.95
MgO	3.55 - 4.02	3.37 - 4.01
SO_3	11.02 - 12.78	11.17 - 12.89
MnO	0.18 - 0.32	0.14 - 0.17
K_2o	0.45 - 0.56	0.79 - 1.01
Na_2O	1.52 - 1.72	1.06 - 1.70
$CaO_{aktivno}$	7.34 - 9.42	4.95 - 6.84

2.3. Mineraloški sastav

Tablica 3.

Mineraloška komponenta	Učešće,%
Anhidrit ($CaSO_4$)	28
CaO	31
Portlandit ($Ca(OH)_2$)	2
Gelenit ($Ca_2Al_2SiO_7$)	12
Periklas (MgO)	2
Kalcit ($CaCO_3$)	15
Kvarc(SiO_2)	5
Žismondit (Ca, Al_2, Si_2O_8, H_2O)	3
Getit (FeO(OH))	2

Mineralni sadržaj hidratisanog deponovanog pepela posle 45, odnosno 120 dana, prikazan je u tablici 4.



TE Kosovo - B, Glavni tehnološki projekat pripreme transporta i deponovanja pepela 11

Tablica 4.

Mineraloška komponenta	Učešće, % Pepeo 45 dana	Učešće, % Pepeo 120 dana
Gips ($CaSO_4 \cdot 2H_2O$)	30	7
CaO	4	3
Portlandit ($Ca(OH)_2$)	4	12
Gelenit ($Ca_2Al_2SiO_7$)	12	11
Periklas (MgO)	1	1
Kalcit ($CaCO_3$)	17	16
Kvarc(SiO_2)	5	5
Žismondit (Ca, Al_2, Si_2O_8, H_2O)	2	
Getit (FeO(OH))	2	2
Tobermorit (XCaO, $SiO_2 \cdot YH_2O$)	18	15
Etringit ($Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 25H_2O$)	6	28

2.4. Gustina, nasipna i zapriminska masa, hidraulička zbijenost

Gustina : 2400 kg/m^3
Nasipna masa : 626.9 kg/m^3
Zapriminska masa : 941.5 kg/m^3
Hidraulička zbijenost : 920 kg/m^3, za hidromešavinu gustine 50% Č

2.5. Definisanje odnosa čvrsto (pepeo) : tečno (voda)

Za odvijanje procesa solidifikacije, neophodno je obezbediti odgovarajući stehiometrijski odnos čvrste i tečne faze. U toku opsežnih laboratorijskih ispitivanja, sa industrijskom i otpadnom vodom termoelektrane, došlo se do jednog šireg opsega osnosa čvrste i tečne faze koji zadovoljava zahteve u pogledu brzine potpunog vezivanja tehnološke vode i očvršćavanja mase. Taj odnos se kreće od 40 - 60% čvrste faze, odnosno pepela, maseno. Pri učešću pepela u količini od 60% proces se ostvaruje u roku od jednog dana, odnosno do pet dana kada je u pitanju učešće pepela od 40%.

U toku industrijskih ispitivanja hidrauličkog deponovanja pepela, proces je vođen sa gustinama hidromešavine između 47 i 51% Č, i pri tom su dobijani zadovoljavajući rezultati u pogledu toka i intenziteta procesa solidifikacije.

Na bazi svih izvršenih ispitivanja, usvojen je maseni odnos pepeo : voda od 45 - 55% čvrstog, kao najpovoljniji.