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## Concrete of our Millennium – Eco Friendly Concrete

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**Abstract.** Scientifically there are no more doubts about the impact of humans on global warming. The raise of earth temperature causes environmentally related problems. Evidences show the most influencing GHG is CO<sub>2</sub>. Many human activities release this GHG as a byproduct. Generally, the two industries contributing to this are the energy production and construction. The GWhrs of Kosovo energy, (in 2013, 5864 GWh) emit kilotons of CO<sub>2</sub>. The emission of CO<sub>2</sub> in 2013 was 7896.0 kton, i.e. 1.3t/MWh. On the other side, the concrete industry, the second most used material, which uses cement contributes with other tons of GHG, almost each ton of cement contributes with one tone of CO<sub>2</sub> emission. The other negative impact of energy sector is production of combustion byproducts. The interest of this study is the residue in the form of ash- Fly ash, which in terms of production is around 1 Mt annually. In 2013 Fly ash generation was 1.5 Mt. This is the physical threat to environment. The aim of this study is the mitigation of CO<sub>2</sub> emissions in Kosovo. It is used worldwide, and we cannot be an exception. The chemically tested Fly ash is added to concrete as cement substitute and the test results showed to positively approve its use. So, each one kg of cement substitution with fly ash is the one kilogram less CO<sub>2</sub> in the atmosphere. Our physical and mechanical tests results showed that our concrete “absorbs” tons of CO<sub>2</sub>, being so friendly to environment, being friendly to people. This is a good track of Kosovo to comply with EU targets on reduction of GHG. The historians, as the named ages: “the stone age”, “the bronze age”, “the iron age”, they must name our millennium: “the concrete age”.

**Keywords:** Kosovo, Fly ash, GHG, Green Concrete, Sustainability.

### 1 Introduction

Concrete is the second most used material after the water [1] [2]. It is a mixture of aggregates, water, cement and admixtures. In an approximation for a mix design of a normal concrete mixture around 300 kg cement is needed for one cubic meter of concrete, i.e. around 12.5 % by weight of concrete. All over the world there are produced more than 2Bt of cement annually. The increase of world’s concrete consumption emerges the need to increase the cement production. Statistics showed that world production of concrete grew permanently. Considering 1994 as referent year with a world total cement production around 1.370 billion tons in 1994, in 2006 the cement production was 2.55 billion tons, in 2013 4.0 billion tons. The approximate calculation, in global scale, shows that production equals 555 kilograms per inhabitant annually [3]. If R. of Kosovo was not an exception, the cement production for each Kosovar would be the same summing the 1Mt of cement production or better said consumed annually.

Fly ash is a residue from lignite combustion in thermal power plants. The Kosovo abundance with lignite deposits around 14 Bt, ranking our country third in Europe for lignite resources [4], and having no other effective alternative of electrical energy production, this has oriented the sustainable energy production of Kosovo towards the use of fossil fuel, i.e. conversion of lignite energy to electrical one. That is the benefit of it. On the other side, this combustion, apart from gaseous emissions produces huge amount of particulate waste in the form of ash: bottom and fly ash. Expressed in percentage of the total ash, around 20% is bottom ash and 80% is fly ash which rises with flue gases. The fly ash is captured by ESP and it is discharged, together with bottom ash as hard waste. The quantity of ash depends on quantity of lignite combustion in the electricity production process. Over the years, the energy demands

have increased the lignite consumption; the electricity production consumes around 7-8 Mt lignite annually. The combustion of this lignite, apart from bottom ash, produces 1Mt of fly ash annually. In 2003 the electricity generation was 3272 GWh, lignite consumption was 5.64 Mt, and fly ash production was 0.9024 Mt. In 2013 the electricity generation was 5864 GWh, lignite consumption 9.38 Mt and fly ash production 1.5008 Mt [4], [5].

CO<sub>2</sub> is a green house gas. It traps heat just like in a greenhouse and in this way enables the earth temperature to be around 15 Celsius degrees. Otherwise without green house effect the earth's temperature would be very low, minus 19 Celsius degrees. There are other GHG such as methane, water vapor, nitrous oxide (N<sub>2</sub>O). The effect of water vapor as GHG, 65% contribution, is greater than CO<sub>2</sub> with 32% contribution, but the levels of H<sub>2</sub>O in atmosphere didn't change, or in our case, it can be said that it is not affected by human activities. If we refer to data about CO<sub>2</sub>, there is an increase of it by 25%, 280 ppm two centuries before. The increase of CO<sub>2</sub> was first declared in 1958, and the result showed 315 ppm. That was a matter of concern with 350 ppm in 1990. On the global scale, the amount of CO<sub>2</sub> in the atmosphere reached 396.0 parts per million in 2013. At the current rate of increase, the global annual average CO<sub>2</sub> concentration is set to cross the symbolic 400 ppm threshold in 2015 or 2016 [6]. This is an indicator that the level of CO<sub>2</sub> is increasing and the earth's temperature consequently. Knowing that approximately 5% of earth's CO<sub>2</sub> is emitted from cement industry production, it is the aim of this study to mitigate the CO<sub>2</sub> emissions from cement industry in the case of R. of Kosovo as part of global activities in cutting the carbon dioxide levels [7].

## **2 Mitigation of Carbon Dioxide Emissions from Concrete Production by Substituting Cement with a Scientifically Reasonable Quantity of Fly Ash**

### **2.1 Cement production and Carbon Dioxide Emission**

Cement is the basic material in concrete industry. The latest increase in construction industry demands greater cement consumption. The Cement production industry consequently contributes with 5% of global carbon dioxide emissions. On average, each year, three tons of concrete are consumed by every person on the planet, i.e. if we assume a 300 kg cement for 1 meter cube of concrete, it comes that around 500 kg cement is consumed by each earth's inhabitant [8].

The technological process of cement production requires high amount of energy, which can be in the form of thermal or electrical. A modern cement production factory consumes around 110–120kWh electrical energy per ton of cement [9]. In the case of Kosovo Power Plant, the specific emission of carbon dioxide is around 1.3t CO<sub>2</sub>/MWh. The calculation of indirect CO<sub>2</sub> emission from electrical energy consumed in cement production is 0.0013 tons of CO<sub>2</sub> per kWh. This shows that per each ton of cement, only from the consumption of electrical energy the CO<sub>2</sub> emission is around 0.15 tCO<sub>2</sub>/t cement [5].

Other indirect carbon dioxide emission is from the thermal process required for heating the rotary kiln where the high temperature is required to perform the calcination process. The heat is provided by burning fossil fuel. It is known that the basic raw material for cement production is limestone CaCO<sub>3</sub>. The heat, typically between 850 deg C and 1340 deg C enables the endothermic decomposition reaction of CaCO<sub>3</sub> into CaO and CO<sub>2</sub>. This endothermic reaction requires 3160 MJ for producing. In the case of cement factory in R. of Kosovo the fuel for heating up the kiln is petcoke. For the reaction of calcinations there are required around 755 Mcal which in MJ is 3161MJ [10]. Each MJ of heat from petcoke emits 97g CO<sub>2</sub> [10]. Thus, the petcoke combustion emits 0.306 t of CO<sub>2</sub> per one ton of lime. The total of these two indirect CO<sub>2</sub> emission is around 0.5 t CO<sub>2</sub>/t of lime, i.e. almost for one ton cement only from these two processes is half ton CO<sub>2</sub> emitted in the air [11].

The increase of concrete demand in construction sector consequently leads to increase of cement production demand. The more cement produced the more carbon dioxide emitted in the atmosphere and this GHG affects negatively the global warming. If not a total replacement of cement, a measure of mitigating its adverse effect could be possible.

## 2.2 Fly Ash- the Particulate Waste from Energy Production Process as Substituent of Cement in Concrete industry

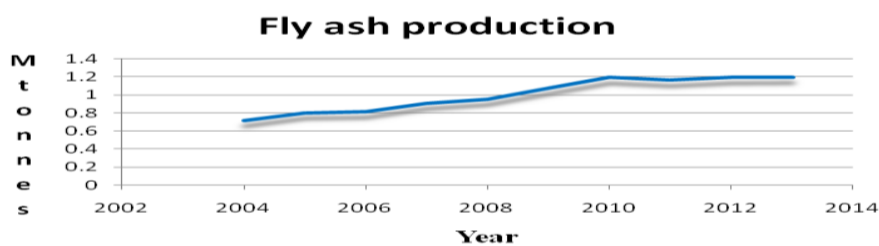
In terms of percentage more than 97% of electrical energy in Kosovo is generated from thermal power stations which use the lignite as fossil fuel. The impossible process of converting the total energy of lignite into electrical energy produces numerous other combustion byproducts. Many of them are emitted through the stack in the atmosphere. One other combustion byproduct is the ash. This ash rises with the flue gases and is captured by ESP. The total of this is around 80% of total ash and is called Fly ash. The rest, around 20% is bottom ash which is not subject of this paper. The quantity of ash that would be produced depends from the ash content in lignite that is around 14-17% by weight [3]. Quantitative analyses of fly ash production can be done based on the specific lignite consumption from the process of electricity generation. The data show that generation of 1MWh of electrical energy, in Kosovo TPP, consumes around 1.4t in Kosova B units, whilst in Kosova A 1.8t/MWh. To facilitate the calculation, a representative average is taken to be 1.6t/MWh [12]. The growth in energy demand over the last years has led to the higher amount of lignite consumption. More lignite burnt means more particulate waste in the form of fly ash. An average of 7-8 Mt lignite consumption in a year produces around 1Mt fly ash presenting a huge environmental threat. In the table below is shown the energy generation, lignite consumption and fly ash production in Kosovo TPPs for the last decade.

**Table 1.** Energy production, lignite consumption and fly ash generation Quantity of ash generated from TPP Kosova A and B [12] [13]

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Energy GWh	3221	3481	3999	3970	4309	4505	5260	5481	5696	5847	5864
Lignite Mt	5.64	5.59	6.27	6.35	7.11	7.46	8.41	9.34	9.11	9.35	9.38
BA+FA Mt	0.9024	0.8944	1.0032	1.016	1.1376	1.1936	1.3456	1.4944	1.4576	1.496	1.5008

**Table 2.** Fly ash production over the last decade in Kosovo TPP

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
FA Mt	0.7219	0.7155	0.8025	0.812	0.9100	0.9548	1.0764	1.1955	1.1660	1.196	1.2006

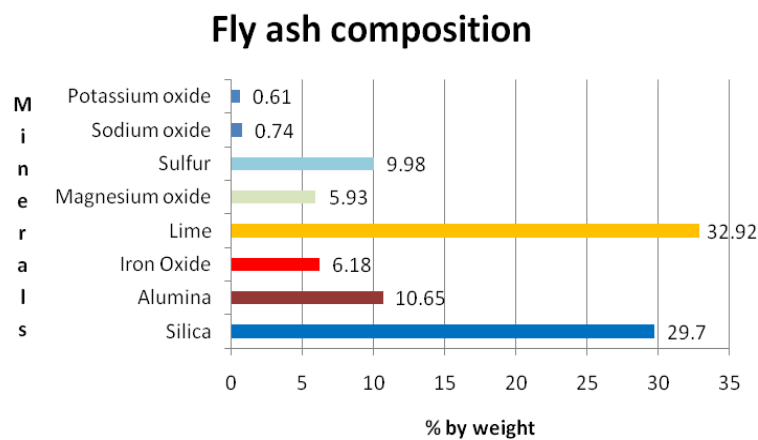


**Fig. 1.** Fly ash production over a ten year period

As it is presented the quantity of this particulate waste is growing due to the growth of energy demand. A possible way to reduce its impact in environment pollution, it is the alternative to utilize it. The first step is done through its chemical analyses. The fly ash of Kosova B TPP has been tested chemically and the chemical and mineralogical composition is shown in the table 3.

**Table 3.** Chemical composition of Kosovo B Fly Ash [5]

Constituent	Chemical formulae	%/ weight
Silica	SiO <sub>2</sub>	29.7
Alumina	Al <sub>2</sub> O <sub>3</sub>	10.65
Iron Oxide	Fe <sub>2</sub> O <sub>3</sub>	6.18
Lime	CaO	32.92
Magnesium oxide	MgO	5.93
Sulfur	SO <sub>3</sub>	9.98
Sodium oxide	Na <sub>2</sub> O	0.74
Potassium oxide	K <sub>2</sub> O	0.61
Loss on Ignition (LOI)		2.09

**Fig. 2.** Kosovo B Fly ash composition

The chemical composition shows that fly ash generally has the same content as cement, but in different percentage. That was the ground state that scientists, engineers based to treat it as possible cement replacement in concrete mix designs or admixture to cement itself.

This fine pulverized grey-in-brown colored material features cementitious and pozzolanic properties. According to EN 450-1 [14], that is European standard for Fly ash in concrete, fly ash is “Fine powder of mainly spherical, glassy particles derived from burning of pulverized coal, with or without co-combustion materials, which has pozzolanic properties and consists essentially of SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub>”.

The classification of fly ash based on the American standard ASTM C618 12a [15]. This standard classifies the fly ash based on the content by mass of lime. If the lime content is greater than 20% by mass, the standard classifies it in Class C Fly ash. The fly ash from Kosovo B TPP showed to have 32.92% CaO (testing method SIST EN 1971-1, clause 3.1) and is definitely classified as class C that in addition of pozzolanic properties has also cementitious properties.

The issue is that we have got million tons of this particulate waste from the energy sector that is not utilized, and on the other hand we have got million tons of CO<sub>2</sub> emitted from cement manufacturing industry. Both, the fly ash and CO<sub>2</sub> have an annual production rate that counts million ton. The impact of this paper is to use the fly ash in concrete as partial cement substituent. The outcome is done on the tests done with different percentage of fly ash replacing cement. Each kilogram of cement substituted by one kilogram of fly ash means one kilogram CO<sub>2</sub> less in Kosovo’s atmosphere. If we consider million tons of concrete production, that would be a great mitigation of this GHG from cement industry.

### **3 The Optimal Quantity of Fly Ash in Replacing Cement in building Eco-friendly Concrete**

#### **3.1 Concrete Mix Designs, Compressive Strength and consistence Tests**

There were designed several concrete mixes. The focus of all these tests has been the possibility of fly ash utilization in concrete as cement substituent. The method followed in test consists on the comparison of compressive strength and consistence of samples with different percentage of Fly ash to the one that it has been referred as referent one, which is designed and built with cement and admixture only. For each intended test there were prepared and cured carefully three samples and the aforementioned properties have been measured. The consistence was measured using the slump method, whilst the compressive strength with the destructive method by pressing them to the strain sustained maximally [1]. The cement is Portland cement, from local SHARRCEM factory, R. of Kosovo with trademark name Forca (CEM.I/52.5N) [16]. The aggregates have been used those from a local quarry, concrete production company NPTSH "VËLLEZERIT E BASHKUAR" shpk. The used aggregates were tested for: sieving method, shape index, determination of particle density and water absorption, sand equivalent test, resistance to fragmentation, resistance to wear, resistance to freezing and thawing, resistance to slat crystallization, chemical analyses and the petrographic examination. The tests were performed in accordance with requirements of standard EN 13043:2002/AC: 2004 [17], and EN 12620 [18].

##### **3.1.1 Referent mix design- Ref. MQDK-CTKK**

This concrete mix design contains in 1m<sup>3</sup>, 300 kg Portland cementm CEM I, 0 kg Fly ash, aggregate, water, TKK hiperplasticizer [19]. The consistency of fresh concrete measured using slump test was 180 mm. There were prepared cubic samples, 15cmx15cmx15cm with the same aforementioned design. The calculated fresh concrete density was  $\rho=2448$ , 2 kg/m<sup>3</sup>.

##### **3.1.2 Mix Design with 15% Fly Ash as Cement Replacement- MQDK-15 FA**

This concrete mix design contains in 1m<sup>3</sup>, 255 kg Cement CEM I, 45 kg Fly ash, aggregate, water, TKK hiperplasticizer. The consistency of fresh concrete measured using slump test was 130 mm. There were prepared cubic samples, 15cmx15cmx15cm with the same aforementioned design. The obtained fresh concrete density was  $\rho=2440$  kg/m<sup>3</sup>.

##### **3.1.3 Mix Design with 20 % Fly Ash as Cement Replacement- MQDK-20 FA**

This concrete mix design contains in 1m<sup>3</sup>, 240 kg Cement CEM I, 60 kg Fly ash, aggregate, water, TKK hiperplasticizer. The consistency of fresh concrete measured using slump test was 140 mm. There were prepared cubic samples, 15cmx15cmx15cm with the same aforementioned design. The obtained fresh concrete density  $\rho=2430$  kg/m<sup>3</sup>.

##### **3.1.4 Mix Design with 25 % Fly Ash as Cement Replacement- MQDK-25 FA**

This concrete mix design contains in 1m<sup>3</sup>, 225 kg Cement CEM I, 75 kg Fly ash, aggregate, water, TKK hiperplasticizer. The consistency of fresh concrete measured using slump test was 90 mm. There were prepared cubic samples, 15cmx15cmx15cm with the same aforementioned design. The calculated fresh concrete density  $\rho=2430$  kg/m<sup>3</sup>.

##### **3.1.5 Mix Design with 30 % Fly Ash as Cement Replacement- MQDK-30 FA**

This concrete mix design contains in 1m<sup>3</sup>, 210 kg Cement CEM I, 90 kg Fly ash, aggregate, water, TKK hiperplasticizer. The consistence of fresh concrete measured using slump test was 80 mm. There

were prepared cubic samples, 15cmx15cmx15cm with the same aforementioned design. The calculated fresh concrete density  $\rho=2420\text{kg/m}^3$ .

### 3.1.6 Mix Design without Fly Ash and without Admixture- Ref. MQDK-C

This concrete mix design contains in 1m<sup>3</sup>, 300 kg Cement CEM I, 0 kg Fly ash, aggregate, water, 0 kg TKK hiperplasticizer. The consistency of fresh concrete measured using slump test was 10 mm. There were prepared cubic samples, 15cmx15cmx15cm with the same aforementioned design. The calculated fresh concrete density  $\rho=2440\text{ kg/m}^3$ .

### 3.1.7 Self Compacting Concrete Mix Design with Fly Ash- SCC ECO-FRIENDLY

This concrete mix design contains in 1m<sup>3</sup>, 400 kg Cement CEM I, 100 kg Fly ash, aggregate, water, TKK hiperplasticizer. The slump flow spread measured was 580mmx580mm. There were prepared cubic samples, 15cmx15cmx15cm with the same aforementioned design. The calculated fresh concrete density  $\rho=2400\text{ kg/m}^3$ .

## 3.2 Review and Comparison of Test Results, Compressive Strength and Consistence of Concrete Samples in Regard to Cement Replacement by Fly Ash in Concrete Mix Designs

### 3.2.1 Compressive strength

The experimental work consists of preparation of seven concrete mix designs. One mix design is prepared only with cement type CEM I, aggregate and admixture-superplasticizer TKK hiperplast 182. That is our referent sample. Four mix designs were done with a certain percentage of fly ash as cement replacement. The quantity of cement replaced with the percentage of fly ash is as in the following rate: 15% (MQDK-15 FA), 20% (MQDK-20 FA), 25% (MQDK-25 FA) and 30% (MQDK-30 FA) of Fly ash by weight of total cement designed for an ordinary concrete class. The water amount was held the same in all mixes. One other mix named SCC ECO-FRIENDLY is self-compacting concrete. The percentage of fly ash in this mix is 25% by weight of concrete. The first mix Ref. MQDK-C is an ordinary mix without fly ash and without admixture. After the curing, the samples have undergone the compressive tests in two different ages, 2 and 7 days. The next is planned after 28 days. The results of each test are presented in the Table 4.

**Table 4.** Compressive strength test results

Mix Design	Age 2 days fc,cube (MPa)	Age 7 days fc,cube (MPa)	Age 28 days fc,cube (MPa)	Increase of CS 2/7 days (%)	Increase of CS 7/28 days (%)
<b>Ref. MQDK-C</b>	14.95	24.35	34.38	61.40	70.83
<b>Ref. MQDK-CTKK</b>	26.95	37.6	47.43	71.68	79.27
<b>MQDK-15 FA</b>	25.05	36.15	49.03	69.29	73.73
<b>MQDK-20 FA</b>	21.43	31.7	46.02	67.60	68.88
<b>MQDK-25 FA</b>	19.21	32.45	47.86	59.20	67.80
<b>MQDK-30 FA</b>	13.94	23.96	39.37	58.18	60.86
<b>SCC ECO- FRIENDLY</b>	44.02	55.95	***	78.68	***

The essence of the testing is to show the reasonability of fly ash utilization as cement replacement. If we refer to referent mix design Ref. MQDK-CTKK with admixture but without fly ash, it can be noticed

a slight deficiency of compressive strength to those with fly ash: 15%, 20%, 25% and 30%. The greater the fly ash content, the lower the discrepancy in compressive strength. The 15% is slightly close to the referent one, the 30% has much lower compressive strength. The wonder that “spoils” this rule is mix SCC ECO-FRIENDLY, self compacting concrete. In two days test, the compressive strength of SCC is 17 MPa higher than of that referent one- Ref. MQDK-CTKK, and for 29 MPa stronger than the one without fly ash and admixture. That is why this is called Eco friendly concrete. In 7 days test, this difference in compressive strength increases, 19 MPa difference to Ref. MQDK-CTKK, 31 MPa to Ref. MQDK-C. One interesting fact that has been taken out form the test results is that even the concrete mix with highest fly ash content- 30% with admixture, MQDK-30 FA, showed equal, or almost the same compressive strength as the mix with cement only without admixture. Four mixes that contain fly ash: MQDK-15 FA, MQDK-20 FA, MQDK-25 FA, MQDK-30 FA definitely showed higher compressive strength than Ref. MQDK-C, mix that has no fly ash and no admixture. At the age of 28 the test results showed that compressive strength of samples MQDK-30 FA is higher than of that referent, Ref. MQDK-C without TKK hiperplast and without fly ash and stronger than referent Ref. MQDK-CTKK with TKK hiperplast. The sample MQDK-25 FA showed to have equal compressive strength as Ref. MQDK-CTKK and Ref. MQDK-C. MQDK-15 FA showed to have higher compressive strength than Ref. MQDK-CTKK and Ref. MQDK-C. All these are in favor of fly ash utilization in concrete industry as cement replacement. And less cement from cement industry means less CO<sub>2</sub> in the atmosphere. This double green concrete: it “absorbs” the particulate waste from the energy sector and it “absorbs” the CO<sub>2</sub> from cement industry.

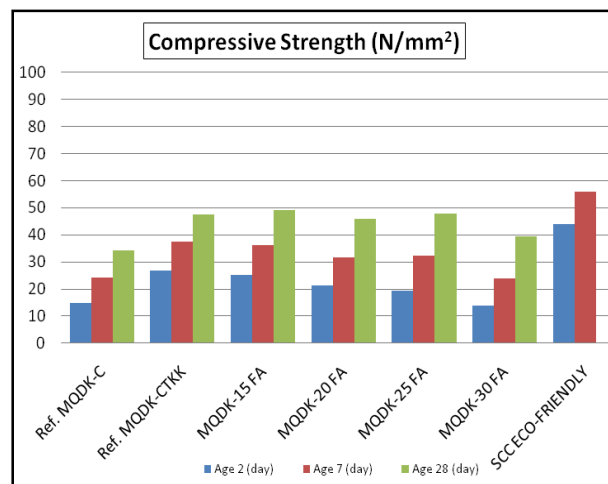


Fig. 3. Compressive strength of mix designs in two different ages

Table 5. Mix designs-content of Cement, Fly ash and TKK Hiperplast 182

Mix Design	Cement (kg/m <sup>3</sup> )	Fly ash (kg/m <sup>3</sup> )	Hiperplast 182 (kg/m <sup>3</sup> )	f <sub>c,cube</sub> (MPa), After 28 days
<b>Ref. MQDK-C</b>	300	0	0	34.38
<b>Ref. MQDK-CTKK</b>	300	0	1.2	47.43
<b>MQDK-15 FA</b>	255	45	1.2	49.03
<b>MQDK-20 FA</b>	240	60	1.2	46.02
<b>MQDK-25 FA</b>	225	75	1.2	47.86
<b>MQDK-30 FA</b>	210	90	1.2	39.37
<b>SCC ECO-FRIENDLY</b>	400	100	4.3	(SCC) f <sub>ck</sub> -55.95*



\* (SCC) fck-55.95- this is the compressive strength after 7 days, there was no CS test of SCC at age 28 days.

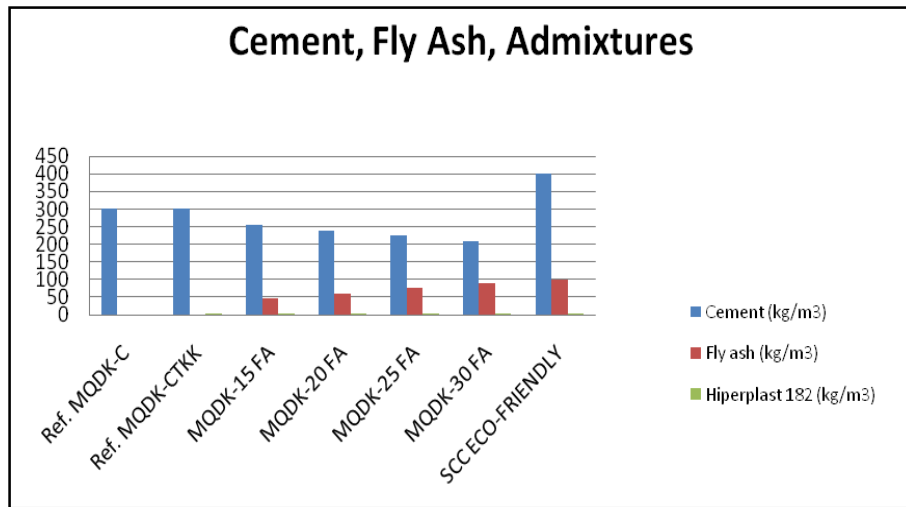


Fig. 4. Content of Cement, Fly ash and TTK Hiperplast 182

Table 6. Water Cement ratio, Water effective cement ratio, C+Fly ash, Water binder ratio

Mix Design	W/C	W <sub>eff</sub> /C	W/(C+k x fly ash)	W/Binder
Ref. MQDK-C	0.700	0.660	0.700	0.530
Ref. MQDK-CTKK	0.630	0.600	0.630	0.480
MQDK-15 FA	0.745	0.710	0.696	0.480
MQDK-20 FA	0.792	0.747	0.720	0.480
MQDK-25 FA	0.844	0.797	0.745	0.480
MQDK-30 FA	0.905	0.854	0.770	0.480
SCC ECO-FRIENDLY	0.500	0.460	0.450	***

The water cement ratio for all concrete mixes has been shown in the Table 6 and Figure 5. From both it can be ascertained that concrete mixes with greater Fly Ash content, except SCC Eco-friendly mix have greater water-cement ratio. This is due to the fact that fly ash has been added in account of cement. Comparing to referent mix Ref. MQDK-CTKK, the SCC eco-friendly mix is in great advantage regarding the w/c ratio. The other mixes that are slightly near this ratio are those with 15% and 20% Fly ash.

According to EN 206-1 fly ash is classified as Type II concrete additive, and then an explanation of **k**-value shall be given for our case. This **k** value is a factor to be considered in the calculations of water in fresh concrete. The amount of fly ash that should be taken into account for **k** value shall meet the requirements:

Fly ash /cement  $\leq 0.33$  by weight. In case of excessive fly ash use, the extra shall not be taken into account in the calculation of water / (cement x fly ash) ratio and the minimum cement content. In our

case, as we have used CEM I 52.5 N, the k value to be taken in calculation is 0.4. From all four mix designs with fly ash addition, 15%, 20%, 25% and 30%, only the one with 30% fly ash exceeds the maximum k value, Fly ash /cement  $\leq 0.33$  [14].

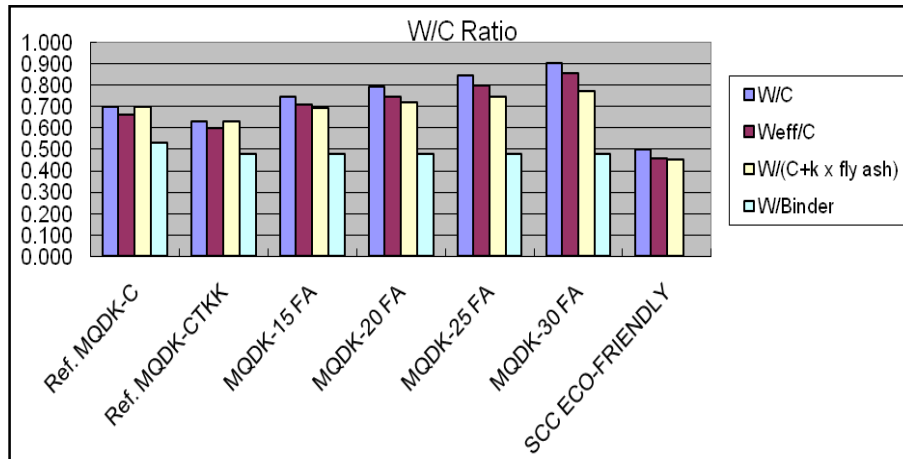


Fig.5. Water cement ratio

### 3.2.2 Concrete Consistency-Slump Test in (mm)

The consistence test of fresh concrete was done by slump method conform SK EN 12350-2. There were achieved different values of consistence. The term consistence is alternative term of workability. According to Glanville, et Al. (1947) [20], the workability is “the property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished. Thus it represents a valuable property of fresh concrete. As we have designed different mix designs with different content of cement that was replaced by fly, the results showed in the table below were different.

Table 7. Consistence of fresh concrete of different mix designs

Mix Design	Slump test (mm)
Ref. MQDK-C	100
Ref. MQDK-CTKK	180
MQDK-15 FA	130
MQDK-20 FA	140
MQDK-25 FA	90
MQDK-30 FA	80
SCC ECO-FRIENDLY	SF1*

\* The slump flow test was done in accordance to EN 206-9:2010, 4 for SCC. The slump flow class according this standard is class SF1, i.e. 550-650 mm [21].

It can be figured out that two different mix designs have not same consistence. The consistence is mostly affected by the quantity of water and cement. In our case we substituted (or not) cement with a certain percentage of fly ash instead, whilst the water content was held the same as in the referent mix.

As presented in the table and chart above, it can be easily stated that the replacement of cement with fly ash reduces the workability. That should be taken into consideration that addition of fly ash absorbs more mixing water.

#### 4 Conclusions

The electrical energy produced in Kosovo TPP is not green at all: 97% is from lignite combustion, less than 3% is green from water. The TPPs except gaseous pollutants that emit in the air, they produce around 1 million ton of hard waste in the form of fly ash that it has not been utilized. By the in-depth test analyses chemically, physically and mechanically, this waste can be partially used in concrete industry as cement substituent.

The compressive strength tests of several mix designs proved that this fly ash from Kosovo TPP can in a high percent be used in concrete. The most suitable percentage of fly ash by weight of cement that can replace cement showed to be around 15-25%. All four mixes with fly ash proved to have greater compressive strength than the mix without fly ash and without admixture that usually this type of concrete is generally produced in Kosovo. Thus, with a little amount of admixture the concrete build with fly ash exceeds the compressive strength of that with cement only.

The cement industry is one of the greatest contributors to CO<sub>2</sub> as GHG. The calculations show that each ton of cement “produces” also 1 ton of CO<sub>2</sub>. Half of the CO<sub>2</sub> is from the chemical reaction of calcinations and half of it from the electrical energy for running the machinery and some portion from fuel combustion for reaching high temperature for producing clinker from lime stone.

Now, we have three facts: fly ash as waste, CO<sub>2</sub> from cement and the one we are interested the replacement of cement in concrete by a reasonable content of fly ash. In terms of number this can be depicted as: if we replace 1 kg cement with 1 kg fly ash the effect is double positive. 1 kg of fly ash is removed from the nature and 1 kg CO<sub>2</sub> is “not” emitted in nature. If generally speaking, from 1 million tons of cement, if we substitute only 25 %, that is 250, 000 tons less fly ash in our land and 250,000 tons less CO<sub>2</sub> emission in the air.

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