Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 7, Issue 05, May -2020

Production and analysis of cement using tire derived fuel (Carbon Black) and Pet-coke as alternative fuels with coal blends

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Abstract: *Cement is a binding material usually produced by burning of fossil fuels like furnace oil, bituminous coal and natural gas in a rotary kiln for making clinker (nodules formed after heating raw mix) from raw materials which includes calcareous (calcium containing) and argillaceous (clay containing). The heating value of these fossil fuels ranges from 9500 Kcal/Kg for furnace oil, 6500 Kcal/Kg and 8500 Kcal/Kg for bituminous coal and natural gas respectively. But due to limited resources and expensiveness of fossil fuels, the cost per ton of cement increases. Alternative fuels like rise husk, bagasse, poultry waste, tires waste and chemicals waste from industries having high heating values are also used in cement industries for cement cost reduction. This research study focuses on the use of tire derived fuel (Carbon black) and petcock as alternative fuels in different proportions with coal blends as cement rotary kiln is the best closed incinerator for these fuels. The coal blend includes local (KPK, Pakistan) Daara coal, African coal, Indonesian coal, pet coke (waste from petroleum industries) and Afghani coal.*

Experimental investigation of tire derived fuel with different coals and the process parameters are studied and results concluded show that alternative fuels can be used with low quality coal blends and the cost per ton clinker reduces without much affecting the clinker quality and hence the cement strength.

Keywords: *Clinker,alite ortricalciumsilicate,beliteor dicalcium silicate*

1. Introduction

The disposal of waste tires is a major threat to environment because they cannot be decomposed easily in ground and also contain heavy metals like lead (Pb) which greatly affects the fertility of land. In an open environment these tires can take fire which is not easily controllable.

The major cost contributing element in producing one-ton cement is fuel. any conventional fuels like coal, furnace oils and natural gas are used to make clinker in cement rotary kiln. These conventional fuels are limitedly available and are also diminishing due to their excessive use around the globe. So alternative fuels usage is the main focus now a day for overcoming the cost for heat production in rotary kiln.

Cement manufacturing is increasing day by day due to its huge demand. Around the globe almost four billion tones cement is produced but it is not meeting the requirements as per actual demand due to heavy construction projects. Since the production of cement requires huge amount of heat energy in the rotary kiln which is difficult to achieve from fossil fuels like coal, natural gas and furnace oil as they are expensive and are hardly available. So in order to produce quality cement as per market demand and with less cost the cement manufacturers are shifting towards alternative fuels. **[1].** The demand of cement in the past few years has successively increased. Coal, oil, natural gas, petroleum coke is few of the traditional fuels used in cement industry for clinker burning. The increasing energy prices and energy concerns have force the cement industries towards the thought of utilizing alternative fuels which can replace the fossil fuels. These alternative fuels include waste oils of industries, non-recycled plastic mixtures and papers, waste tires, waste biomass and the waste water sludge. **[2].** To overcome the dependency of fossil fuels in cement industry, alternative fuels are the cheapest available high heat energy source. The use of alternative fuels like tire derived fuel and refused derived fuel also helps in reducing the green-house gases. Furthermore, new technologies have been introduced for the utilization of alternative fuels in an efficient way and without harming the environment. **[3].**

Globally the solid wastes contribution in increasing soil, water and air pollution is countable largely. These solid wastes contain large amount of heat energy in them. Cement production requires huge amount of heat energy in rotary kiln for its manufacturing and it is the only source where these solid wastes can be utilized for heat generation with the prevention of land, air and water pollution. **[4]**

Cement rotary kiln plays an important role in the burning of different unwanted wastes like oils, plastics, sewerage sludge and waste tires due to high retention times and high heat exposure. These solid and liquid wastes contain contaminants that are absorbed in the clinker during its burning and thus the environment is not polluted. **[5].**Cement plant performance is greatly increased by the use of alternative fuels in rotary kiln due to their high heating values. The main objective of the current proposal is to study the effect of alternative fuels in rotary kiln and to check its performance. The performance of cement plant is mainly measured from the thermal efficiency which manly contributes in the cost per ton of the cement produced.

Hence less flue gases emission. One of the major things to reduce the greenhouse gases is to replace the fossil fuels with alternative fuels which have high heating values and replaces the fossil fuels. Hence the cost per ton of cement is also reduced and less green houses are produced due to less consumption of fossil fuels. **[6].** In the U.S million metric tons of waste has been diverted from landfills by using single stream recycling. Recycling of solid municipal waste in is about 30 % of the total waste in U.S. Material recovery facilities for sorting the recycled municipal streams are also not efficient in 100 % sorting. It contains non recycled high energy plastic contents and fibers. One possible way to utilize this high energy-dense solid waste is to incinerate them in cement rotary kiln as solid recovered fuel which works as an alternative fuel. This Solid recovered fuel is capable of replacing the fossil fuels such as coal, coke, natural gas, furnace oil, diesel oil in many industries and power plants. **[7].** Alternative fuels have more heating values and are easily and cheaply available to be used in cement rotary kiln for clinker burning. Alternative fuels are mostly produced from wastes and the main cost on them occurs because of their processing. Alternative fuels are the major source of prevention of renewable sources. **[8].** Cement industries are providing benefit to the world by the consumption of alternative fuels up to 30-40 % which include waste plastic bags, waste tires, wood chips and switch grass. By utilizing these alternative fuels at high temperatures and close environment in the cement rotary kiln their quantity is reduced from environment otherwise they would be dumped openly by making stock piles and in the land which is risky in both cases. If dumped in an open environment, they can catch fire and produce extreme heat and hazardous gases. If dumped in land, they can decrease the fertility of land because they contain heavy metals like lead and arsenic. **[9].** With increasing trend and demand of energy in industrial and commercial sectors, such high demand is difficult to be fulfilled because of the increasing population and as well as industrialization. This high demand is leading to the diminishing of the natural resources of energy such as the fossil fuels including coal, natural gas and crude oil. Cement sector consumes high energy for clinker production in a rotary kiln. For this increasing demand of the cement in around the globe the cement industries are facing extreme restrictions from government organizations on the emissions of flue gases. For this purpose, the cement industries are heading towards alternative fuels utilization for heat energy generation including the tire derived fuel, the biomass etc. which produces the desired heat required for clinker production and also lowers the cost per ton of the cement produced. **[10].** The efficient way to utilize the waste is to get heat energy from it. Waste can be used as a fuel source or in combination with fuel if it has better chemical energy content in it. The size of organic matter and the moisture contents present in the waste accounts for most of the chemical energy content. The most efficient way of utilization of these waste is to use them as an alternative fuel source with fossil fuels for heat generations. Different alternative fuels include RDF, TDF, Rice husk, Bagasse etc. Researchers have been done on the use of alternative fuels in cement rotary kilns for heat generation for clinkerization process. These alternative fuels are easily burnable in cement rotary kilns owing to their high temperatures in a closed insulated system, high retention times in a lengthy kiln and alkaline environment. **[11]**

2. Material and methods

2.1. Processing:

Samples of different bituminous coals to be used in the experiment were collected from the yard of Bestway cement industry. The samples of coals collected were received from Afghanistan, Africa, Local mines of Khyber Pakhtunkhwa in Dara Adam Khel district of Pakistan and Indonesia. Similarly, samples of Tire derived fuel i-e carbon black and pet-coke were also collected.

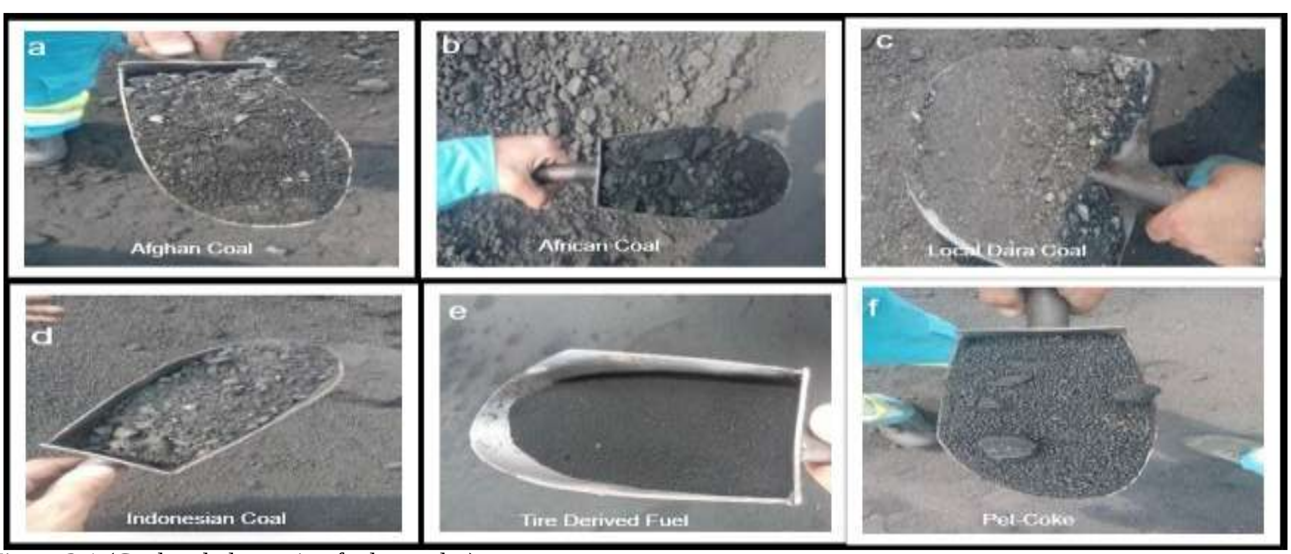

Figure 2.1 (Coal and alternative fuel samples)

2.2 Proximate Analysis:

Proximate analysis of coals and alternative fuels were carried out. The analysis included amount of sulfur, amount of ash, amount of heat calculated as gross and net calorific values respectively. Moisture content was also find out which almost remained the same for all coals i-e 8~10 %.

The equipment's used for the proximate analysis were moisture analyzer, bomb calorimeter for finding out the gross and net calorific values, furnace at high temperature for finding out the volatile matter, XRF and XRD machines for finding out the elemental analysis of raw meal and coal including silica, iron, calcium, sulfur etc.

In the table mentioned below, only the major parameters are incorporated.

Table 2.1(Proximate analysis of coal and alternative fuels)

Specifications				
	Sulfur (%)	**Gross Calorific value (Kcal/Kg coal)**	**Net Calorific value (Kcal/Kg coal)**	**Ash (%)**
Limits for good operation	**< 1**	**> 6000**	**> 5800**	**-**
Coal Type				
African	0.73	6344	6121	15.71
Afghan	0.62	6441	5832	16.9
Indonesian Low. quality	0.35	6099	5551	11.44
P. Coke	**5.93**	**8435**	**8014**	0.66
Tired Derived Fuel	**4**	**6791**	**6662**	17.39
Local (Darra)	**2.8**	**5931**	**5625**	22.96

Table 2.1 clearly reflects that alternative fuels including tire derived fuel and pet-coke have higher calorific values as compared to coals whereas the amount of sulfur in the alternative fuels is more then as compared to different origins coal.

2.3 Kiln Feed analysis

Kiln feed analysis was also carried as in below table 2.2.

Table 2.2 (Kiln feed analysis)

Parameter	**Alternative Fuel**	**South African Coal**
SiO2	13.16	13.97
Al_2O_3	3.48	3.31
Fe_2O_3	2.23	2.29
CaO	42.23	42.62
MgO	1.76	1.6
SO_3	0.05	0.11
Na_2O	0.24	0.13
K_2O	0.68	0.72
SO_3(C-5)	1.06	0.63
Lime saturation factor	99.44	99.75
D.O.C	97.58	95.51
Silica Modulus	2.36	2.49
Alumina Modulus	1.47	1.45

Table (2.2) indicates that raw meal composition was kept almost same for both trials.

The major raw material ingredient of cement is lime (CaO) commonly known as quick lime. It reacts with Silicon di oxide and forms different components which contribute in the initial and final strengths of the cement. These include the formation of alite or tri-calcium-silicate (3Cao.SiO2 or C3S) and belite or di-Calcium-silicate (2CaO.SiO or C2S). Iron Oxide (Fe2O3) plays an important role inside the kiln by facilitating the solid-solid chemical reaction with the formation of a liquid phase which brings down the eutectic temperatures of the reacting substances and hence consuming less heat. Also the iron oxide contributes in giving grey color to the cement. Magnesium Oxide (MgO) helps in the formation of active sites enhancing the development of tri-calcium silicate from di-calcium silicate. An excess of magnesium oxide is considered harmful for the cement because it forms cracks in long terms.
Sulfur tri oxide (SO3) is formed by combustion from the elemental sulfur present in raw meal or in the fuel. The presence of sulfur in excess blocks the heating path of the kiln and preheater due to which production suffer so it is beingbalanced by the introduction of alkalies (sodium oxide Na2O and potassium oxide K2O) in the system which are then captured in the clinker.
Lime saturation factor or LSF determines that that how much of the introduced lime CaO is being converted into C3S and C2S after chemical reactions with silica. In the same way silica modulus and alumina modulus are the parameters indicating the conversion of silicon di oxide and aluminum oxide into respective compounds after heating in the rotary kiln.

2.4First Phase:
In the first phase, the raw material was burnt in the rotary kiln using 100 % African origin coal. Kiln operational parameters were noted. Also the lab analysis of clinker obtained by burning 100 % African coal were carried out.

2.5Second Phase:
In the second phase, the raw material was burnt in the rotary kiln with different proportions of coal and alternative fuels. Kiln operational parameters were noted while clinker analysis were also carried out.

3. Results and discussion

3.1 Clinker results when 100 % African Coal was combusted
When 100 % South African coal was combusted in the rotary kiln for burning the raw materials annexed in graph for the formation of clinker, the alite (C3S) formed was 50 % while belite formed was 26.38 %.

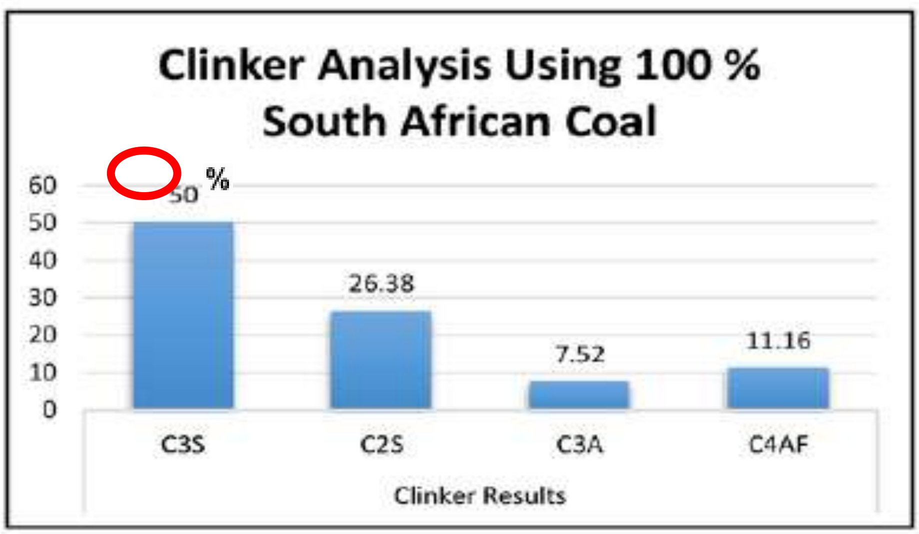

Figure 3.1 (100 % South African Coal vs clinker C3S)

3.2 Clinker analysis when coal blend was burnt with alternative fuels in different proportions:
When different coal blends and alternative fuels in defined proportions were combusted in rotary kiln for the raw materials annexed below, then the tri-calcium silicate results of clinker are as mentioned in below graph.

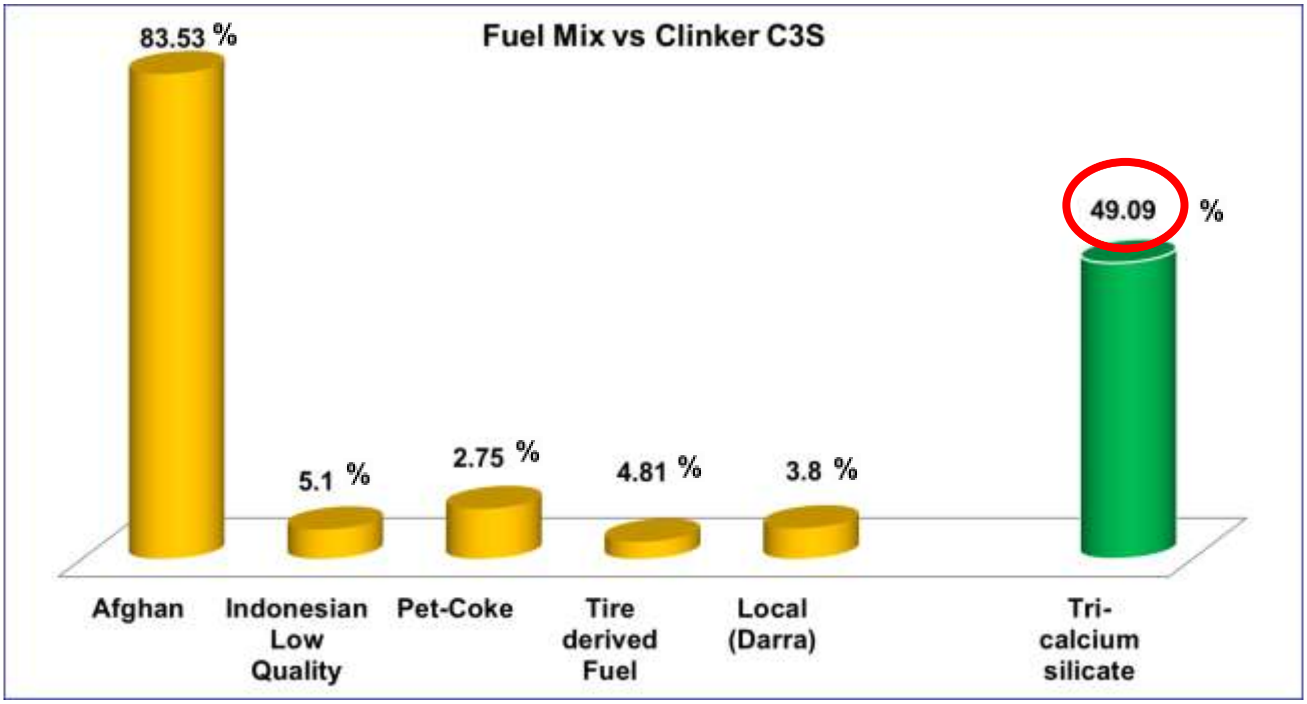

Figure 3.2 (Alternative fuels and coal blends vs clinker C3S)

Imported African coal burning was stopped and low quality coals with 2.75 % pet-coke and 4.81 % tire derived powdered fuels were consumed. The results of clinker obtained were having 49.07 % tri-calcium-silicate C3S which remained in the satisfactory range.

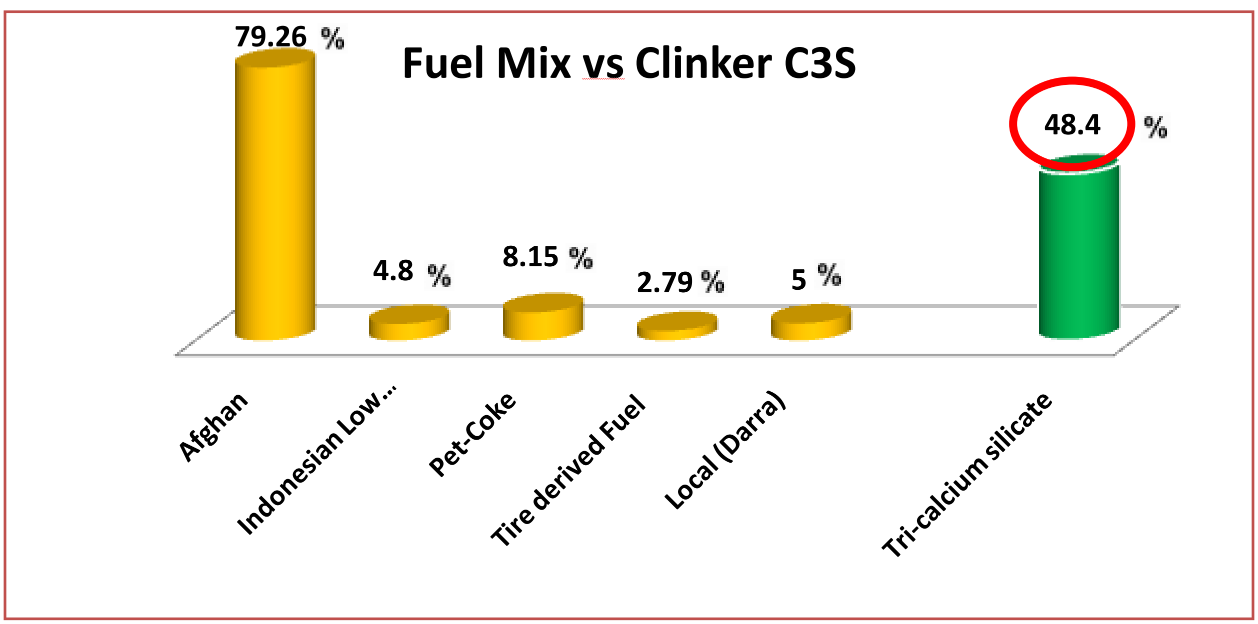

Figure 3.3(Alternative fuels and coal blends vs clinker C3S)

In another case the amount of Afghan origin coal was reduced while the pet-coke and tire derived fuels were also changed to 8.15 % and 5 % respectively. The clinker results for tri-calcium silicate were found in satisfactory range of 48.4 % which did not affect the cement strength comparatively.

3.3 Clinker Cost per ton clinker:

Clinker cost per ton clinker was found using 100 % African coal and on the other hand mixture of coals and alternative fuels in different proportions. Below mentioned table clearly reflects thatthe cost per ton of the clinker has reduced significantly using alternative fuels in specified proportions with coal blends.

Table 3.1 (Clinker cost per ton using 100 % African coal and alternative fuels with coal blends)

Coal Origin	Rate / Ton	Fuel Ratio %	Actual	
			Tons / day	Cost
Fuel cost/ Ton clinker using 100 % South African Coal				
South Africa	20500	**100**	420	**2303.99**
Fuel cost/Ton clinker using alternative fuels				
Afghan	18500	79.26	372.52	**2160.69**
Indonesian Coal	10480	4.8	22.56	
Pet-coke	15150	5.15	24.21	
Carbon Black	7500	2.79	13.11	
Dara Coal	12802	8	37.6	

Table 3.1 reflects that for burning 100 % African origin coal the cost per ton of clinker was more i-e 2303.99 PKR while on the other hand when pet-coke and tire derived fuels were mixed with coal blends and burnt in specified proportions then the cost per ton of clinker reduced significantly i-e 2106.69 PKR. Similarly, the cost per ton of clinker for other percentages of alternative fuels and coal blends were calculated and found less than that for burning 100 % African origin low sulfur imported coal.

3.4 Flue gases analysis:

Flue gases analysis was carried out at preheater stack. It was found that flue gases remained in satisfactory range as per**national environmental quality standards(NEQ's).**

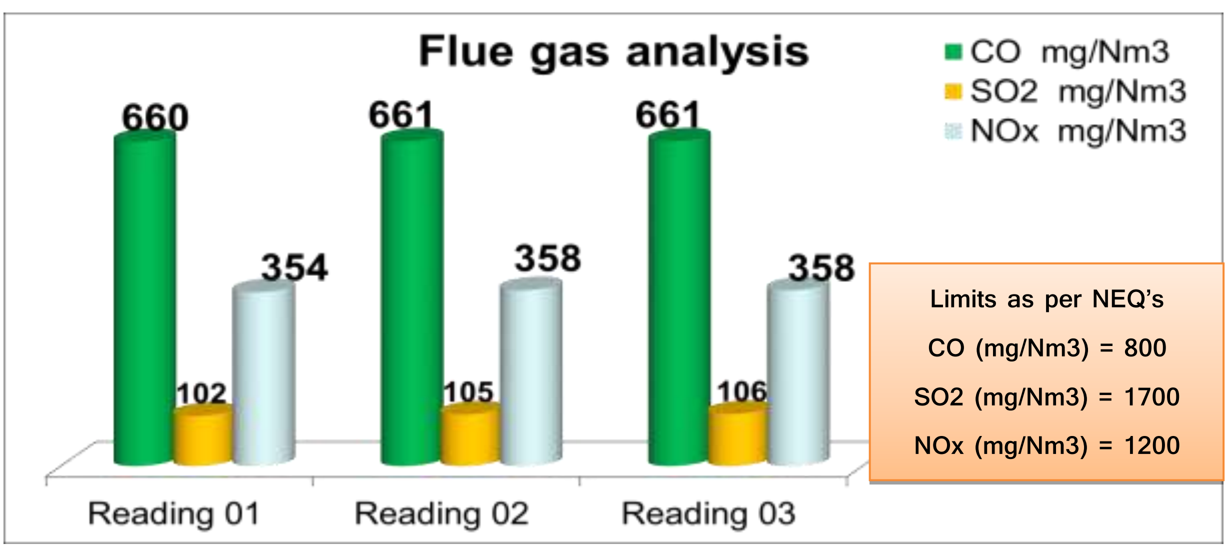

Figure 3.4 (Flue gases analysis)

Conclusion:

From the results and analysis of clinker, it is cleared that using 100 % South African coal the results are almost the same as using the alternative fuels and coal mixture.
The compressive strengths of cement mostly depend on the amount of Tri-Calcium silicate (C3S) and Di-Calcium silicate (C2S). Using alternative fuels and coal blends the amount of C3S and C2S obtained in clinker remained nearly the same and the strength of cement is thus not affected.
Similarly, from the above environmental analysis of flue gases it is obvious that the emissions of SOx ,NOx and CO remained under the provided EPA (Environmental Protection) and NEQ's (National Environmental Quality Standard's).
Since South African Coal (imported coal) is mostly used in all cement industries across Pakistan because of its higher calorific value and less impurities for the purpose of making good clinker in terms of chemical analysis and also for stabilize kiln operations but it is costly in terms of transportation, so from the above mentioned results it is cleared that local impure coals along with some good quality coals mixture can be used with alternative fuels (in the above case Carbon black and pet-coke) and can produce good quality, low cost and environmental friendly clinker.

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