Suitability of PMDC Degyari Coal for Use in Cement Industry

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Abstract

The selection of fuel is of significant importance in cement industry as the fuel cost comprises 40% of the total cement manufacturing cost. Furnace Oil, Natural Gas and coal are the three available options for kiln firing. The Coal being cheapest is economically more suitable but is difficult to handle. However, in order to ensure the cost effectiveness of process, coal arises as the suitable choice.

This research paper investigates the suitability of PMDC Degyari Coal, Quetta to be used in cement industry. A detail analysis of the coal was carried out including its proximate analysis, gross calorific value, hard groove grindability index, total sulfur, and ash analysis. Volatile Matter, Ash Content, Fixed Carbon, Gross Calorific Value and Moisture Content of the coal understudy are within the limits prescribed for usage of coal in the cement industry[1]. However, the sulfur content of coal and the hard groove index are the problematic areas. On this basis it is suggested that the coal understudy can be used in cement industry after mixing it with imported coal of low sulfur content and high hard groove grindability index.

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Introduction

The increasing demand of coal in the cement industry is quite evident due to economic factors associated with the cement manufacturing yet the coal must fulfill certain requirements in order to ensure the cement quality and equipment safety.

Advantages of using coal

+ Coal having lower hydrogen content, have a lower difference of gross calorific value and net calorific value as compared to that of furnace oil and natural gas.

+ Coal flame has high emissitivity and the heat transfer is carried out more easily than natural gas. On an average kiln efficiency is 2-3% higher while using coal than natural gas [1].

+ Coal ash being absorbed in the kiln increases the quantity of raw meal. The requirement of iron oxide, silica, and alumina is reduced while firing coal in the cement kiln.

+ Unlike fuel oil, coal ash does not contain vanadium content which are corrosive in nature to the hot parts of kiln.

Disadvantages of Coal usage

+ Coal has a variable composition and it is inevitable to blend coal before firing in the kiln in order to ensure the appropriate firing.

+ Coal ash has a variable composition as well and it effects the raw material composition and therefore needed to be monitored on regular basis

+ Precautions are required to be carried out during coal storage/grinding so that the risk of spontaneous combustion is minimized.

Brief Description of Experimental Work

Determination of Total Moisture (ASTM D3302)

Weighed a cleaned and dry Petri dish to 4 decimals. Spread approximately 1 gram of coal sample on the bottom of the dish. Weighed it to 4 decimals. Placed the dish into the oven. Closed the oven tightly. Dried the sample in the oven for 1 hour at 105- 110°C. Opened the dessicator and oven. Placed Petri dish in the dessicator to cool for 15 minutes. Weighed dish to 4 decimals.

Formula Used

% Moisture M= $\dfrac{(W2-W3)}{(W2-W1)}$ x 100

Where

W1= weight in grams of empty dish = 21.3274 gm

W2= weight in grams of dish and sample before heating = 22.3274 gm

W3= weight in grams of dish and sample after heating = 22.2046 gm

% Moisture M = $\dfrac{(22.3274 - 22.2046) \times 100}{(22.3274 - 21.3274)}$

$= 12.28 \%$

Determination of Air Dry Loss

Weighed a clean dried Petri dish. Took 1 gm of coal sample in a Petri dish and placed in an air drying oven at 15°C above room temperature for 24 hours. Reweighed the Petri dish along with sample.

Formula Used

% Moisture M= $\dfrac{(W2-W3) \times 100}{(W2-W1)}$

Where

W1= weight in grams of empty dish = 22.5623 gm

W2= weight in grams of dish and sample before heating = 23.5623 gm

W3= weight in grams of dish and sample after heating = 23.5162 gm

% Moisture M = $\dfrac{(23.5623 - 23.5162) \times 100}{(23.5623 - 22.5623)}$

$= 4.61 \%$

Determination of Volatile Matter (ASTM D3175)

Heated an empty clean crucible with lid for 7 minutes at 900°C, cooled it for 1 minute on a metal plate and then 10 minutes in the desiccator. Finally weighed the crucible with lid to 4 decimals.

Placed approximately 1 gram of sample of coal in the crucible and placed the lid and weighed to 4 decimals. Carefully knocked the crucible bottom against a clean, hard surface. The coal sample forms as even layer of uniform thickness on the bottom of the crucible. Placed the crucible with coal sample in a muffle furnace at 900°C for exactly 7 minutes using stop watch. Removed the crucible and let it cooled for 1 minute on a metal plate, subsequently in the desiccator for ten minutes. Finally weighed the crucible with lid to 4 decimals.

$$\% \text{ Volatile Matter} = \left[\frac{(W2-W3) \times 100}{(W2-W1)} \right] - M$$

Where

W1 = weight in grams of empty crucible with lid = 33.4265 gm

W2 = weight in grams of crucible, lid and sample before heating = 34.4265 gm

W3 = weight in grams of crucible, lid and sample after heating = 33.8838 gm

M = moisture content of sample in percent = 12.28 %

$$\text{Percentage of Volatile Matter} = \left[\frac{(34.4265 - 33.8838) \times 100}{(34.4265 - 33.4265)} \right] - 12.28$$

$$= 41.99 \%$$

Determination of ASH (ASTM D3174)

Weighed a clean, dry quartz dish with lid to 4 decimals. Spread 1 or 2 grams of coal sample to form an even layer on the bottom of the dish. Weighed dish, lid and coal sample to 4 decimals.

Placed the quartz dish without lid in the muffle furnace at room temperature. Then raised the furnace temperature to 500°C with in 30 minutes and subsequently to 815°C within the next 60-90 minutes.

Kept the temperature of 815°C constant until the weight of quartz dish does no longer change (one hour at 815°C is sufficient for the most coal samples).

When the weight is constant, i.e complete incineration has been accomplished removed the dish from the furnace, placed the lid on it, and cooled it on a metal plate for 10 minutes and subsequently in a desiccator for 15 minutes.

Then weighed dish with lid to 4 decimals, brushed off the ash completely and weighed the empty dish with lid. The weight of ash resulted as the difference.

Calculation:

$$\% \text{ Ash} = A = \frac{(W3-W4) \times 100}{(W2-W1)}$$

Where

W1 = weight in grams of quartz dish with lid = 34.6218 gm

W2 = weight in grams of quartz dish, coal and lid = 35.6218 gm

W3   = weight in grams of quartz dish, ash and lid after heating = 35.5375 gm

% Ash = A $= \dfrac{(W3-W4) \times 100}{(W2-W1)}$

$= \dfrac{(35.6218 - 35.5375) \times 100}{(35.6218 - 34.6218)}$

= 8.43 %

Determination of fixed Carbon

Fixed carbon was determined by the following formula

Fixed carbon = 100- (Moisture + Voltile +Ash)

= 100 – (12.37 + 41.99 + 8.43)

= 37.33 %

Determination of Gross Calorific Value (ASTM D2015)

1.   Filled the bomb bucket with 2000ml, of water from pipette tank. Allowed water stream from the pipette tank to tank to hit inside wall of the bomb bucket.

2.   Pulled up on the bomb cover latch and lift the cover to the couple's vertical position.

3.   Placed the Bomb bucket inside the bomb bucket well making sure that the indent in the bottom of the bomb bucket is positioned towards the front of the analyzer. Folded the handle down flat on top of the bomb bucket.

4.   Attached the carrying handle to the bomb by inserting the pins on the end of the handle, into the holes around the top of the bomb.

5.   Lowered the bomb, using the carrying handle, into the bomb bucket taking care not to disturb the sample. Centered the bomb over the indent in the bottom of the bucket.

6.   Removed the carrying handle from the bomb and shake the excess water from the handle back into the bomb bucket.

7.   Grasped the insulated portion of the bomb fuse leads, when inserting them into the bomb jacks, so the water in the bucket is not touched.

8.   Checked to see that there were, no oxygen bubbles coming from the bomb.

9.   Closed the bomb bucket lid and press down on the front lid to latch it.

10.   Started by the pressing START.

11.   The result window displayed the amount of time left before ignition.

12.   During post fire, the top line displayed the bucket water temperature rise (Delta-T). The result window displayed the time remaining for analysis.

13.   After analysis is complete, lift the Bomb Bucket lid to the complete vertical position. Hold the cloth under the stirrer and dry the blade. Removed the bomb fuse lead and dry

them with a cloth. The insulation must be kept dry or the precision of the answers will degrade.

14. Removed the bomb from the bomb bucket, using the bomb-carrying the handle, and pour the Bomb Bucket Water back into the Reservoir Tank.

15. Use a clean lint free cloth and wiped the inside and outside of the Bomb Bucket.

16. Discharged the bomb slowly by running the knurled valve counter- clock wise.

17. Unscrewed the Bomb Cap remove the Sample Holder Assembly straight up with a steady pressure.

18. Examined the interior of Combustion Chamber for the soot or evidence of incomplete combustion.

19. Measured any remaining fuse length and subtract it from the programmed fused length. Edited the corrected fuse length on the analyze screen.

20. Used "Edit last result menu" to edit or insert value of fuse wire length, moisture and sulfur and press exit to change the results accordingly.

21. The changed or net results will be printed on printer if printer is on.

The result obtained was
Gross Calorific Value = 6158 (Kcal/Kg)

Determination of Sulfur

For the random determination of sulfur X-Ray Fluorescence (XRF) was calibrated. 1 gm of coal was mixed with the raw meal containing zero sulfur and the sample was run in the machine. The obtained results were verified by Escha Mixture Method (ASTM D3177).
The Sulfur obtained was 4.90 %.

Hardgroove Grindability Index of Coal

A representative gross sample of the coal should be collected; the gross sample should be reduced such that it can pass through number 4 sieve (4.75 mm).

Preparation of test sample

Divided the quantity of the material retained from 4.75 mm sieve to 1Kg by continuous rifling. Air dry the 01 kg sample for neither less then 12 hr and nor greater then 48 hrs. Crushed the air dried sample such that it can passed through sieve # 16(1.18 mm) but is retained on sieve # 30 (600 μm). Each time sieve about 200 grams of sample for 5 minutes, such that sieve # 16(1.18 mm) is on the top of sieve # 30 (600 μm). Pluverized the material retained on sieve # 16(1.18 mm) again and again until all the material passed from sieve # 16(1.18 mm). Mix the sample retained of on sieve # 30 (600 μm) and reduced the weight up to 120 grams by continuous rifling and finally dedust the 120 grams sample on sieve # 30 (600 μm) for 5 minutes.

Procedure:

Cleaned the HGI machine completely and space the eight balls evenly in the grinding bowl, set the automatic stopping device such that it will stop after 60 ± 0.25 revolutions.

From the sample obtained after dedusting took 50 grams sample and distribute evenly in the grinding bowl. Fasten the bowl in position and make sure that the load is fully applied to the driving spindle, operate the machine for 60 ± 0.25 revolutions.

Removed the bowl from the machine carefully, brush the adhering coal into sieve # 5/8 inches (16 mm) placed on the sieve # 200 (75 µm) with the closely fitted receiver pan. Empty the balls, bowl and the grounded coal on sieve # 5/8 inches (16 mm) into the sieve # 200 (75 µm) to the receiver pan. Replaced the sieve #5/8 inches (16 mm) with cover and shake the sieve # 200 (75 µm) for 10 minutes and carefully brush the coal dust from the bottom of sieve # 200 (75 µm) to receiving pan. Repeated the shaking and cleaning of the sieve twice for 5 minutes duration. Now weighed the material retained and passed from sieve # 200 (75 µm), if the sum differs for more than 0.75 grams from the initial weight of 50 grams, rejected and repeated the test.

Calculations

Calculate the weight of the passed material as:

Passed material = 50 grams – retained material (grams)

Passed material = 50 grams – 45.8 (grams)

Calculated the HGI from the calibration chart by plotting weight passed against HGI of standard coal samples.
The HGI of the sample turned out to be is 39.

Ash Analysis

X-Ray Fluorescence (XRF) was employed for ash analysis. For this reason 10 gm coal ash was prepared by abovementioned method (ASTM D3174). The coal ash was then run into the XRF apparatus after adding binder. The result obtained were as under

Table 1 : Composition of Ash

Sr. No.	Constituents	%age
1	Silica (SiO_2)	20.16
2	Alumina (Al_2O_3)	14.32
3	Iron (Fe_2O_3)	37.83
4	Lime (CaO)	2.04
5	Magnesia (MgO)	5.5
6	Potassium Oxide (K_2O)	0.67
7	Sodium Oxide (Na_2O)	3.24
8	Sulfur Trioxide (SO_3)	6.28
9	Chlorine (Cl)	0
10	Loss on ignition (LOI)	9.96

Analysis of PMDC Degyari coal

The sample understudy was thoroughly tested under the standard operating procedures practiced in Quality Control Department of Bestway Cement Chakwal. The results of the analysis are as under.

Table 2 : Composition of Coal

Sr. No.	Test Name	Result
1	Air Dry Loss %	4.61
2	Inherent Moisture %	7.67
3	Volatile Matter %	41.99
4	Ash %	8.43
5	Fixed carbon %	37.33
6	Sulfur %	4.90
7	Gross Calorific Value (Kcal/Kg)	6158
8	Hard Groove index	39

Economics of PMDC Degyari Coal to be used in Cement Industry

The comparison of the cost effectiveness of PMDC Degyari coal and the imported coal used in the Bestway Cement Chakwal is as under.

Table 3 : Comparison of Degyari and Imported Coal

Parameters	PMDC Degyari	Imported Coal
Total Moisture %(As Received Basis)	12.28	15.00
Volatile Matter %(As Received Basis)	41.99	34.00
Sulfur %(As Received Basis)	4.90	0.80
Hard grove Index	39.00	60.00
Gross Calorific Value (As Received Basis)	6158.00	6290.00
Price per ton (without Carriage)	4800.00	6500.00
heat consumption Kcal/Kg-Clinker	726.00	726.00
Calculations		
Hydrogen % (ARB)	4.29	3.83
N .C .V (K.cal/Kg)	5860.98	6001.16
Cost of coal/Kg (Rs)	4.80	6.50
Coal consumption(Kg)/ton of clinker	123.87	120.98
Cost per ton Clinker (Rs)	**594.58**	**786.35**

It is therefore inferred that local is cheaper by far then the imported coal but the sulfur content is higher and hard groove index of local coal is lower than the limits normally prescribed. It is therefore recommended that the coal understudy coal sample can be utilized in the cement industry by appropriate mixing with imported coal. It should be noted that the final coal mix should not contain sulfur more 2.5% and hard groove index not less than 50.

Results and Discussions

Significant of Typical Coal Content in Cement Industry and the sample analyzed

Volatile Matter, Ash Content, Fixed Carbon, Gross Calorific Value and Moisture Content of the coal understudy are in the limits prescribed for usage of coal in the cement industry. However, the sulfur content of coal and the hard groove index are the not in the suitable range. However the PMDC Degyari coal can be used in the cement industry after mixing it with imported coal with low sulfur content and better HGI.

Ash Content [2]

Coal ash is absorbed by the kiln feed while firing it coal in the kiln. Coal ash mainly comprises of silica, alumina and iron oxide. Laterite is added in the raw material in order to give cement the desired color and mainly provide iron oxide in the cement. The high content of iron in the coal ash may decrease the requirement of additional raw material. Moreover the requirement of silica and alumina is also reduced while using coal in the cement kiln. Coal ash lowers the lime saturation factor of the raw mix considerably and increases the silica modulus. Coal of high ash

content up to 30% can be economically fired in rotary kiln. The permissible ash content of the coal is governed by the composition of the raw materials, more particularly the limestone. If the ash content is increased from 10 to 20%, lime saturation factor decreases by about 3.5 points. High coal ash may react with the kiln lining and damage it. High ash content also decreases the flame temperature of kiln.

In PMDC Degyari coal the high Iron Oxide content are significant, hence the quantity of laterite requirement will be decreased by using this coal. The Sulfur trioxide content will decrease the Gypsum requirement for cement manufacturing in later stages.

Sulfur

When a fuel containing sulfur is burnt nearly whole of this element is evolved as gaseous sulfur dioxide, but a small amount may be retained in the ash as sulfite or sulfide. Sulfur oxide is also a source of atmospheric pollution. Presence of sulfur also causes Spontaneous combustion in stored coal.

If sulfur introduced through coal becomes higher, then serious build-ups are formed which causes problems in the ducts and cyclone vessels of pre-heater and pre-calciner. Under these circumstances, some of the Kiln gases need to bypass to reduce the sulfur cycle. Moreover sulfur content of coal increases the SO_3 content of clinker and therefore the quantity of gypsum to be utilized in cement is reduced. This in turn will increase the cost per ton of cement as gypsum is much cheaper than that of clinker.

Volatile Matter

The optimum content of volatile matter in the pulverized coal is about 20%. It generally ranges from 18-30% and so need to achieve this value by judicious blending of coals. Coals with lower volatile matter can be utilized economically in rotary kilns by grinding it to a higher fineness than coal with a higher volatile content.

Coal with high volatile matter, as is the coal understudy, are easier to grind and burn. The VM of PMDC Degyari coal is 41.99 and so it can be ground with 20% residue on 90 micron sieve. This will decrease the cost of grinding of coal. Moreover high volatile matter allows long flame in the kiln so that localized point of heating are not formed and provide uniform temperature. Fixed carbon is burnt easily as the volatile matter will easily be liberated.

Gross Calorific Value

Gross Calorific Value provides the heat required for raw material burning. The coal under discussion has 6158 kcal/kg, which is quite reasonable. Such a high GCV will allow coal to be blended with low grade coals having low GCV and high ash content.

References:

[1] Majid, Abdul, Hand Book for Cement Engineers, Institute of Professional Advancement, 2004, pp 123.

[2] Gupta OP, Fuel Furnaces and Refractories, Romesh Chandar Khana, 2003, pp 12-15.