NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 2, ISSUE 4APR.-2015

MINIMIZATION OF CEMENT KILN DUST

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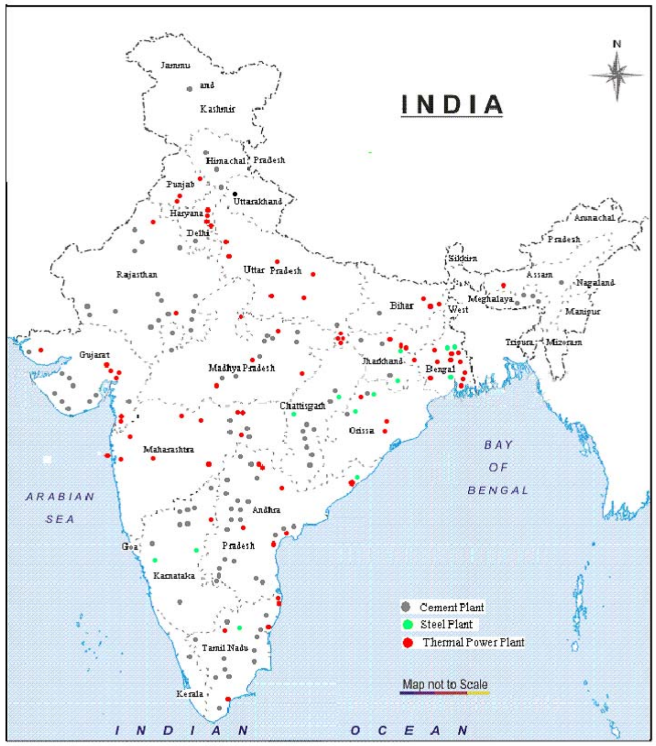
INTRODUCTION

Cement refers to the commodities that are produced by burning mixtures of limestone and other minerals or additives at high temperature in a rotary kiln, followed by cooling, finish mixing, and grinding. This is the manner in which the vast majority of commercially-important cementations materials are produced in the United States. Cements are used to chemically bind different materials together. The most commonly produced cement type is "Portland" cement, though other standard cement types are also produced on a limited basis.

Cement plants produced 99.8 million metric tons of cement. Worldwide production accounted for about 2.5 billion metric tons. As with most large manufacturing industries, by-product materials are generated. These industrial by-product and waste materials must be managed responsibly to insure a clean and safe environment.



HISTORICAL BACKGROUND

The term cement is commonly used to refer to powdered materials which develop strong adhesive qualities when combined with water. These materials are more properly known as hydraulic cements. Gypsum plaster, common lime, hydraulic limes, natural pozzolana, and Portland cements are the more common hydraulic cements, with Portland cement being the most important in construction.

Cement was first invented by the Egyptians. Cement was later reinvented by the Greeks and the Babylonians who made their mortar out of lime. Later, the Romans produced cement from pozzolana, an ash found in all of the volcanic areas of Italy, by mixing the ash with lime.

Cement is a fine grayish powder which, when mixed with water, forms a thick paste. When this paste is mixed with sand and gravel and allowed to dry it is called concrete.

About ninety-nine percent of all cement used today is Portland cement. The name Portland cement is not a brand name. This name was given to the cement by Joseph Aspdin of Leeds, England who obtained a patent for his product in 1824. The concrete made from the cement resembled the color of the natural limestone quarried on the Isle of Portland in the English Channel. The balance of cement used today consists of masonry cement, which is fifty percent Portland cement and fifty percent ground lime rock. The first cement manufactured in the United States was produced in 1871 by David Saylor of Coplay, Pennsylvania.

There are two types of raw materials which are combined to make cement:

- Lime-containing materials, such as limestone, marble, oyster shells, marl, chalk, etc.
- Clay and clay-like materials, such as shale, slag from blast furnaces, bauxite, iron ore, silica, sand, etc.

It takes approximately 3,400 lbs. of raw materials to make one ton (2,000 lbs.) of Portland cement. The mixture of materials is finely ground in a raw mill. The resultant raw mix is burned in a rotary kiln at temperatures around 4482 degrees Celsius to form clinker. The clinker nodules are then ground with about 3 % gypsum to produce cement with a fineness typically of less than 90 micrometers.

CHEMISTRY

Non-hydraulic cement such as slaked limes (calcium hydroxide mixed with water), harden due to the reaction of carbonation in presence of the carbon dioxide naturally present in the air. Calcium oxide is produced by lime calcinations at temperatures above 825 °C (1,517 °F) for about 10 hours at atmospheric pressure:

$$CaCO_3 \rightarrow CaO + CO_2$$

The calcium oxide is then *spent* mixing it to water to make slaked lime:

$$CaO + H_2O \rightarrow Ca\,(OH)_2$$

Once the water in excess from the slaked lime is completely evaporated (this process is technically called setting), the carbonation starts:

$$Ca\,(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

This reaction takes a significant amount of time because the partial pressure of carbon dioxide in the air is small. The reaction of carbonation requires the air be in contact with the dry cement, hence, for this reason the slaked lime is non-hydraulic cement and cannot be used under water.

Conversely, the chemistry ruling the action of the hydraulic cement is the hydration. Hydraulic cements (such as the Portland cement) are made of a mixture of silicates and oxides, the four main components being:

Belite ($2CaO\cdot SiO_2$);
Alite ($3CaO\cdot SiO_2$);
Celite ($3CaO\cdot Al_2O_3$);
Brownmillerite ($4CaO\cdot Al_2O_3\cdot Fe_2O_3$).

The reactions during the setting of the cement are:

$$(3CaO\cdot Al_2O_3)_2 + (x+8)\,H_2O \rightarrow 4\,CaO\cdot Al_2O_3\cdot xH_2O + 2\,CaO\cdot Al_2O_3\cdot 8H_2O$$
$$(3CaO\cdot Al_2O_3) + 12\,H_2O + Ca\,(OH)_2 \rightarrow 4\,CaO\cdot Al_2O_3\cdot 13\,H_2O$$
$$(4CaO\cdot Al_2O_3\cdot Fe_2O_3) + 7\,H_2O \rightarrow 3\,CaO\cdot Al_2O_3\cdot 6H_2O + CaO\cdot Fe_2O_3\cdot H_2O$$

And during the hardening (the chemistry of the reaction of hydration is still not completely clear):

$$(3CaO\cdot SiO_2)_2 + (x+3)\,H_2O \rightarrow 3\,CaO_2\cdot SiO_2\cdot xH_2O + 3\,Ca\,(OH)_2$$
$$(2CaO\cdot SiO_2)_2 + (x+1)\,H_2O \rightarrow 3\,CaO_2\cdot SiO_2\cdot xH_2O + Ca\,(OH)_2$$

MANUFACTURING PROCESS OF CEMENT INDUSTRIES

Cement Raw Materials

The silicon, aluminum, and iron needed as cement process ingredients do not always have to come from clay, shale, and sand found in a quarry. Power plant fly ash and boiler ash have raw material characteristics. Spent aluminum potliner is both an energy source and a raw material substitute candidate.

The production of cement takes place with following steps:

1.Quarrying, Dredging, and Digging

Quarrying of limestone and shale is accomplished by using explosives to blast the rocks from the ground. After blasting, huge power shovels are used to load dump trucks or small railroad cars for transportation to the cement plant, which is usually nearby.

The ocean floor is dredged to obtain the shells, while clay and marl are dug out of the ground with power shovels. All of the raw materials are transported to the plant.

2.Grinding

After the raw materials have been transported to the plant, the limestone and shale which have been blasted out of the quarry must be crushed into smaller pieces. Some of the pieces, when blasted out, are quite large. The pieces are then dumped into primary crushers which reduce them to the size of a softball. The pieces are carried by conveyors to secondary crushers which crush the rocks into fragments usually no larger than ¾ inch

3.**Blending**

After the rock is crushed, plant chemists analyze the rock and raw materials to determine their mineral content. The chemists also determine the proportions of each raw material to utilize in order to obtain a uniform cement product. The various raw materials are then mixed in proper proportions and prepared for fine grinding.

4.**Fine Grinding**

When the raw materials have been blended, they must be ground into a fine powder. This may be done by one of two methods:

1.The wet process of fine grinding is the older process, having been used in Europe prior to the manufacture of cement in the United States. This process is used more often when clay and marl, which are very moist, are included in the composition of the cement. In the wet process, the blended raw materials are moved into ball or tube mills which are cylindrical rotating drums which contain steel balls. These steel balls grind the raw materials into smaller fragments of up to 200 of an inch. As the grinding is done, water is added until a slurry (thin mud) forms, and the slurry is stored in open tanks where additional mixing is done. Some of the water may be removed from the slurry before it is burned, or the slurry may be sent to the kiln as is and the water evaporated during the burning.

2.The dry process of fine grinding is accomplished with a similar set of ball or tube mills; however, water is not added during the grinding. The dry materials are stored in silos where additional mixing and blending may be done.

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5.Burning

Burning the blended materials is the key in the process of making cement. The wet or dry mix is fed into the kiln, which is one of the largest pieces of moving machinery in the industry. It is generally twelve feet or more in diameter and 500 feet or more in length, made of steel and lined with firebrick. It revolves on large roller bearings and is gradually slanted with the intake end higher than the output end.

As the kiln revolves, the materials roll and slide downward for approximately four hours. In the burning zone, where the heat can reach 3,000 degrees Fahrenheit, the materials become incandescent and change in color from purple to violet to orange. Here, the gases are driven from the raw materials, which actually change the properties of the raw materials. What emerges is "clinker" which is round, marble-sized, glass-hard balls which are harder than the quarried rock. The clinker is then fed into a cooler where it is cooled for storage.

6.Finish Grinding

The cooled clinker is mixed with a small amount of gypsum, which will help regulate the setting time when the cement is mixed with other materials and becomes concrete. Here again there are primary and secondary grinders. The primary grinders leave the clinker, ground to the fineness of sand, and the secondary grinders leave the clinker ground to the fineness of flour, which is the final product ready for marketing.

7.Packaging/Shipping

The final product is shipped either in bulk (ships, barges, tanker trucks, railroad cars, etc.) or in strong paper bags which are filled by machine. In the United States, one bag of Portland cement contains 94 pounds of cement, and a "barrel" weighs four times that amount, or 376 pounds. In Canada, one bag weighs 87 1/2 pounds and a "barrel" weighs 350 pounds .Masonry cement bags contain only seventy pounds of cement. When cement is shipped, the shipping documents may include "sack weights."This must be verified by the auditor since only The cement is taxable. "Sack weights" must be excluding.

WASTE GENERATION FROM CEMENT INDUSTIES

Every industry produces the useful products along with the waste products. The major solid waste produce by the cement industry is 'CEMENT KILN DUST'.

Process related dust sources:

*Drilling and blasting
*Crushing and grinding - Limestone, coal and clinker
*Kiln
*Clinker cooler

Fugitive dust sources:-

*Conveyor transfer points
* Open material stock piles
* Discharge from hoppers
* Leaking joints
* Raw material transport and handling through dumpers and pay loaders

LEGAL FRAMEWORK

Industrial operations in the country are subject to regulation through a plethora of Legislations enacted from time to time. Important among the Acts which concern cement industries from the environmental view point are:
* Air (Prevention & Control of Pollution) Act, 1986
* The Environmental (Protection) Act 1986
* Forest (Conservation) Act, 1980
* Water (Prevention & Control of Pollution) Cess Act, 1974
* Water (Prevention & Control of Pollution) Cess Act, 1977
* The Public Liability Insurance Act, 1991

WASTE MANAGEMENT FROM CEMENT INDUSTRY

1 GREEN CEMENT

Green cement is a cementations material that meets or exceeds the functional performance capabilities of ordinary Portland cement by incorporating and optimizing recycled materials, thereby reducing consumption of natural raw materials, water, and energy, resulting in a more sustainable construction material.

The manufacturing process for green cement succeeds in reducing, and even eliminating, the production and release of damaging pollutants and greenhouse gasses, particularly CO_2.

Growing environmental and increasing cost of fuels of fossil origin has resulted in many countries in sharp reduction of the resources needed to produce cement and effluents (dust and exhaust gases).

2 EFFICIENT AND SUSTAINABLE USE OF CEMENT KILN DUST:-

Cement Kiln Dust is the fine grained, solid, highly alkaline waste removed from cement kiln exhaust gas by air pollution control devices like,

- Cyclones and
- Electrostatic precipitator

Due to globally growing demand of cement results in the production of large quantities of cement kiln dust. The disposal of this fine dust is very difficult and possesses the environmental threat. To overcome this major problem researches are being carried out in different parts of the world. To find out efficient use of cement kiln dust along with the determination of its chemical properties. The major uses of Cement Kiln Dust are in cement production, soil stabilization, pavements, agriculture, sewage treatment, mines reclamation, manufacturing of bricks.
Recently the general trend all over the world is the reutilization of the various industrial wastes or by-products in order to reduce or prevent the environment pollution and keep the balance of the environment. Major concern should be given to separate the harmful chemicals from Cement Kiln Dust and proper disposal of Cement Kiln Dust without causing environmental threat.

Cement Kiln Dust is composed of mixture of calcined and uncalcined feed materials, fine cement clinker, fuel combustion by products, and alkali compounds.

TYPICAL COMPOSITION OF CEMENT KILN DUST (Haynes and Kramer, 1982)

Constituent	% by weight
$CaCO_3$	55.5
Fe_2O_3	2.1
SiO_2	13.6
KCl	1.4
CaO	8.1
MgO	1.3
K_2SO_4	5.9
Na_2SO_4	1.3
$CaSO_4$	5.2
KF	0.4
Al_2O_3	4.5
Others	0.7

3 IMPACTS OF CEMENT KILN DUST:-

Several impacts are discussed in more detail below.

Cement and nitrogen oxides:-

Nitrogen in the atmosphere is very stable. It takes a very hot flame to disrupt it. Nitrogen oxides are therefore generally produced only by processes involving high temperature combustion. But cement kilns run very hot. The cement industry is responsible for about 1.5% of all nitrogen oxides emissions.

Cement and global warming:-

The cement industry affects the global warming issue in two major ways:

- The conversion of limestone to clinker involves the thermal decomposition of calcium carbonate into calcium oxide and carbon dioxide (calcinations). The latter is released to the atmosphere in large quantities from the kilns during operation.
- The cement manufacturing process is a large consumer of carbon-based fuels (generally powdered coal or natural gas), whose principal oxidation product is carbon dioxide.

In terms of greenhouse gas emissions, cement manufacture (NAICS code 327310) is responsible for 71.6 trigrams (million metric tons, TG) of carbon dioxide equivalent emissions, according to 2000 data. This includes 30.5 TG from fuel consumption, and 41.1 TG from non-fuel sources. solid waste at the same time, is to use a readily available source of lime that has already been calcinated, and will not add additional carbonates. On average, producing a ton of Portland cement clinker results in the release of a ton of carbon dioxide to the atmosphere, with 60% due to calcinations, and 40% due to fuel consumption. Replacing a percentage of the cement with the waste materials will result in an acceptable (in fact, in some cases, an improved) product, with a proportional decrease in the amount of carbon dioxide released.

EPA itself has weighed in on the matter of taking advantage of this opportunity to combine pollution prevention and waste recycling.

4 USE OF CEMENT KILN DUST (CKD):-

The majority of Cement Kiln Dust is recycled back into the cement kiln as raw feed. In addition, new technology has allowed the use of previously land filled Cement Kiln Dust to be used as raw feed stock. Recycling this by-product back into the kiln not only reduces the amount of Cement Kiln Dust to be managed outside the kiln, it also reduces the need for limestone and other raw materials, which saves natural resources. The value of Cement Kiln Dust is not limited to its use as a raw material for return to a Portland cement kiln.

Soil Stabilization:-

Waste Stabilization is currently one of the common beneficial uses for Cement Kiln Dust. Some wastes can be physically unstable and chemically hazardous.The adsorptive capacity and cementations properties of CKD allow it to reduce the moisture content and increase the bearing capacity of the waste, respectively; while its alkalinity allows CKD to neutralize waste, immobilize hazardous constituents, and control residual odor. CKD is a cost – effective alternative to other conventional waste treatment materials like lime and cement. The Turner Fairbanks Highway Research Center indicates in its user guidelines for granular base that CKD has been used as a Stabilizing and Solidifying agent for environmental remediation.

CKD is also used to stabilize soft or wet soil that is unsuitable for engineering purposes.

CKD can be used to improve the properties of this soil in situ, and as an activator in pozzolanic stabilized base mixtures.

CKD can be successfully in place of lime or Portland cement for roadway base stabilization.

Waste Solidification/ Stabilization:

Mixing wastes in treatment tank:-

A use of CKD plays an integral part of treatment. Hazardous waste is treated with CKD is shown in following table:-

Aqueous wastes	Metal solid	Plating sludge	Organic &Inorganic liquids
Spent acids	Petroleum solids	Drilling mud	Organic paint/ink/lacquer
Spent caustics	Adhesives/epoxies	Catalyst wastes	Ethylene glycol antifreeze
Waste oils	Incinerator residues	Resins/tar sludge	Leach ate contaminated wastes
Brine solutions	WWT sludge	Contaminated soil	Hazard sandblasting wastes

Hydraulic Barrier In A Landfill Liner Or Cover:-

Landfill liner or covers must maintain a low permeability to contain leachate and prevent infiltration of water, respectively. Clay has generally been used to provide these low permeability layers in landfill liners or covers; however the cementations properties of CKD make it a possible substitute for clay.

Laboratory and field studies have shown that CKD can be compacted at an optimum moisture content to achieve permeability's between 10^{-5} and 10^{-9} cm/sec which may be suitable for many landfill applications.

Mine Reclamation:-

The use of CKD as partial hydraulic filler for backfilling coal mine shafts and tunnels. Because of its fine particle size and high alkali contents, CKD is also being premixed to neutralize acidic media and effluent from mining and mineral processing industries. For instance, CKD was used to neutralize a chemical pond containing acidic sulfates. The attempts were only partially successful because the particular CKD used was very coarse reported on the stabilization of sulfuric mine tailings to prevent metal release and acid drainage. The dust also has the potential to replace fly ash for controlling the spread of fires in coal mines. CKD has also been used as a binder in pelletizing iron ore fines for recycling in steel making. It has also applications as coagulant for dewatering of waste sludge from tin rolling mill.

Land Application As Agriculture Soil Amendment:-

Optimizing soil chemistry is a critical process in agriculture. Liming agents are frequently used to neutralize acidic soil. Because of its alkalinity, CKD can be, and has been, successfully used as a liming agent in acidic soil.

The Clemson University Department of crop and soil states that the reasons for using Aglime are to neutralize the acidity of soil and to add calcium and magnesium to the soil. Aglime does this; however, since carbonates are not very finely soluble in water, limestone must be ground very finely and mixed with the soil to be effective at neutralizing CKD contains higher percentage of oxides and hydroxides than of carbonates, and because it is very fine, it is more reactive than ground limestone.

Because of the high lime and potassium concentrations, CKD is used as a soil amendment or fertilizer in many parts of the world. The acid neutralizing capacity of the lime in CKD counteracts the acidic soils that result from years of farming. Neutral soils are a better growing environment for crops and also enhance herbicide effectiveness. The dust may provide potassium and trace metals that are also depleted from agricultural soils due to plant withdrawal requirements.Beneficial Uses of Cement Kiln Removed from the Cement Manufacturing Process:-

Uses of CKD	Quantity of CKD beneficially reused, metric tons
Soil / Clay Stabilization / Consolidation	533,365
Waste Stabilization / Solidification	213,675
Cement Additive / Blending	183,228
Mine Reclamation	152,756
Agricultural Soil Amendment	33,546
Sanitary Landfill Liner / Cover Material	15,042
Wastewater Neutralization / Stabilization	12,302
Concrete Products	374
Pavement Manufacturing	12,066
Beneficial Use Not Provided	3,657
Total	**1,160,011**

From PCA member company survey for 2006

CONCLUSION

Cement Kiln Dust (CKD) is a significant by-product material of the cement manufacturing process. Over the past several years dramatic advances have been achieved in the management and use of cement kiln dust, thus reducing its dependency on landfill disposal. The majority of CKD is recycled back into the cement kiln as raw feed. In addition, new technology has allowed the use of previously land filled CKD to be used as raw feed stock. Recycling this by-product back into the kiln not only reduces the amount of CKD to be managed outside the kiln, it also reduces the need for limestone and other raw materials, which saves natural resources. The value of CKD is not limited to its use as a raw material for return to Portland cement kiln. There are many other beneficial uses of CKD including waste solidification or soil stabilization, hydraulic barrier in a landfill liner or cover, land application, as agricultural soil amendment, flow able fill, sorbent to remove sulfur dioxide from cement kiln flue gas etc and helps conserve energy.

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