Investigation Study of Locally Production of Lime

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Abstract: ***Quicklime is used in several applications, mainly in the production of hydrated lime, which is a major component in the chemical and food industries (sugar, food drinks, and manufacture of some medicines, leather, paper, plastics and petrochemicals). The quick lime production process including extraction and preparing of limestone and burning it at high temperature (1200 - 1500) ℃ in a kiln, then cooling it by air, storing portion of it, and the remaining portion is used to create slaked lime by reacting with water. The objective of project is produce high quality of quicklime and slaked lime from limestone. Three samples of limestone were taken from three different places in the Sudan: Aljabalain, Kasala and Red sea. The three samples were analyzed and the Red sea sample was excluded because the percentage of calcium carbonate is low. The other samples were burned in the kiln at temperature 1200 c and analyzed, the result of analysis showed that the limestone of Aljabalain is the best because it contains a high percentage of calcium carbonate. Quicklime and slaked lime were produced with a high degree of purity.***

Keywords: Limestone, Calcium Carbonate CaCo3, carbonate sedimentary rock, material Lime

1. Introduction

Quicklime and slaked lime are both referred to as "lime" in general. Lime is utilized in a variety of goods, each of which is tailored to the needs of a certain market. For instance, lime and its derivatives are used in water purification to precipitate impurities, as a binder in building and construction, and as a fluxing agent in the refining of steel.

The neutralization of acidic components in industrial effluent and flue gases also makes substantial use of lime. Quicklime and hydrated lime were utilized in construction as early as 1000 B. C. by a number of civilizations, including the Greeks, Egyptians, Romans, Incas, Mayas, Chinese, and Mogul Indians. The Romans utilized limewater as a medicine and were aware of its chemical qualities; they used it, for instance, to bleach linen. By decarbonizing limestone, calcium oxide (CaO), also referred to as quicklime or burnt lime is produced ($CaCO_3$). Quicklime is "slaked" with water to create slaked limes, which primarily contain calcium hydroxide ($Ca(OH)_2$). Slaked lime is made up of hydrated lime, milk of lime, and lime putty (dispersions of calcium hydroxide particles in water). (1)

Objectives

In this study the limestone is collected from different places of the Sudan: Kassala, Aljabalain and red sea.

Although there is a large quantities of lime stone stock in Sudan, but lime is imported because The Manufactured lime is low Purity. The main objective of this study is produce lime with high purity from limestone in the Sudan to replace the imported lime.

The main Objectives are:

1) Collect and analysis limestone from three areas Kasala, Red sea and Aljabalian.
2) Produce and perform an experimental examination of high purity lime.

2. Literature Review

Meier et al. found that concentrated solar energy can be used in place of fossil fuels to drive the endothermic calcinations reaction. In a modern lime plant, CaCO3 CaO + CO2 at temperatures above 1300 K has the potential to reduce CO_2 emissions by 20%, and in a traditional cement plant, up to 40%. The cost of solar - produced lime is between 128 and 157 $/t, or roughly twice the amount at which it is now sold. (2)

Produced by (Oates, et al) the quicklime by the thermal decomposition of limestone at temperatures above 900°C. About half of the quicklime made had reacted with water to produce calcium hydroxide (in the form of milk or lime putty). Lime products are generally the most used available and most cost - effective alkaline chemicals and had used in a wide variety of industrial processes. In many countries, the largest had used for the production of iron and steel, followed by building and construction, environmental protection, and the chemical industry. (3)

Examined by (Boke, et al) the possibility of obtaining hydraulic lime at relatively low temperature. Limestone containing diatoms was heated at a relatively low temperature (850 °C), then slaked and carbonated. After heating and slaking, calcium silicate giving hydraulic to the lime was indicated by XRD and SEM–EDS analyses. Results were show that the production of hydraulic lime at a relatively low calcination temperature (850 °C) was possible with 15th century kilns. (4)

It was found by (Kemperl) that coarser granulations of lime have better optical properties than finer granulations. The hydration temperature does not have an appreciable impact on the optical properties, but influences the intermediate, i. e. the calcium hydroxide particle sizes and subsequently the particle sizes of the precipitated calcium carbonate. (5)

Found by (Scherer, et al) the most efficient and ecological way to calcine limestone and dolomite had the use of modern shaft kilns. The PFR lime kiln has established itself worldwide for this type of product. (6)

Designed by (Bakolas, et al) the mortars with the same mixing ratio of lime/aggregates and evaluated till 18 months of curing. The obtained results revealed that lime powder mortars present a higher carbonation rate and higher values of compressive strength compared to lime putty mortars. (7)

Changed by (Marvila, et al) of hydrated lime in mortars by a kaolinite clay with ideal plasticity parameters. Clay amounts of 0, 25, 50, 75, and 100 wet. - % were used as replacement of hydrated lime in mortars. The results showed that with up to 50 wet - % of hydrated lime replacement, it is perfectly feasible to fulfill with technological parameters of standards. (8)

Introduced by (Steel Authority of India Limited, et al) employed several innovative repair methodologies and design changes and applied superior materials to improve the life of lime kiln. These investigations resulted in reducing overall down time of kilns. Thereby improving calcined lime quality and productivity for steel making. (9)

3. Manufacture of Lime

The lime making process consists of the burning of calcium and/or magnesium carbonates at a temperature between (900 Ċ and 1500 Ċ) which is sufficiently high to liberate carbon dioxide, and to obtain the derived oxide. For some processes significantly, higher burning temperatures are necessary, for example dead - burned dolomite.

The calcium oxide product from the kiln is generally crushed, milled and/or screened before being conveyed to silo storage. From the silo, the burned lime is either delivered to the end user, or transferred to a hydrating plant where it is reacted with water to produce hydrated or slaked lime. (1)

Lime processes mainly contain the following basic steps, which are illustrated:

1) Extraction of limestone.
2) Limestone storage and preparation.
3) Fuels storage and preparation.
4) Calcinations of limestone.
5) Quicklime processing.
6) Quicklime hydration and slaking.
7) Storage of products.

Limestone storage and preparation

Limestone is crushed to the appropriate size range, which is normally 5 to 200 mm depending upon the kiln used. it is Washing is sometimes used to remove natural impurities such as silica, clay and the very fine particles of limestone. This washing aids the burning process by leaving free space between the stones for combustion air circulation, thus reducing the amount of excess air and saving electrical energy.

Fuels storage and preparation

In lime burning, the fuel provides the necessary energy to calcine the lime. It also interacts with the process, and the combustion products react with the quicklime. Many different fuels are used in lime kilns. In this study the fuel uses is furnace.

Calcinations of limestone

The term “calcinations of limestone” refers to the process of its thermal decomposition into quicklime and carbon dioxide. The lime burning process typically involves:

1) Providing sufficient heat at above 800 C^0 to heat the limestone and to cause decarbonation.
2) Holding the quicklime for the requisite time at a sufficiently high temperature (typically in the range 1200 to 1300 C^0 to adjust reactivity.

A large variety of techniques and kiln designs has been used over the centuries and around the world. The famous designs are vertical shaft kiln, rotary kiln and pre rotary kiln. In this study, a prerheater rotary kiln was selected.

Stone properties such as strength before and after burning, dust generation and product quality must be considered when choosing kiln technology. Many lime producers operate two or more types of kiln, using different sizes of limestone feed, and producing different qualities of lime.

Heat transfer in lime burning can be divided into three stages: (10)

a) Preheating zone. Limestone is heated from ambient to above 800 °C by direct contact with the gases leaving the calcinations zone (i. e. products of combustion, excess air and CO_2 from calcination).
b) Calcinations zone. Fuel is burned in preheated air from the cooling zone and (depending on the design) in additional “combustion” air added with the fuel. This produces a temperature of over 900°C (900 to 1300) and causes dissociation of the limestone into quicklime and carbon dioxide.
c) Cooling zone. Quicklime leaving the calcinations zone at 1300°C is cooled by direct contact with “cooling” air, part or all of the combustion air, which in return is preheated. (4)

Quicklime processing

Lime is commonly produced by the heating of natural limestone in a process known as “claiming. ” To calcine limestone, the raw material must be heated to temperatures ranging from 1, 350° F to 1, 650º F, a temperature hot enough to melt a silver coin. During this process, the heat drives off carbon dioxide (CO_2), leaving calcium oxide (CaO) and small amounts of various impurities. The objective of processing run - of - kiln (ROK) quicklime is to produce a number of grades with the particle sizes and qualities required by the various market segments. (11)

A number of unit processes are used, including screening, crushing, pulverizing, grinding, air classifying and conveying. ROK lime is often screened (typically at about 5 mm) to remove a less pure “primary” fines fraction. The (ROK) is crushed, screened and store. The products are stored in bunkers, from which they can be either dispatched directly, or transferred to another plant for grinding or hydrating. Particle size requirements vary from relatively coarse products used for soil stabilization to very finely divided products for specialist applications.

Production of Slaked lime

The hydration of lime involves the addition of water in a hydrator. The quantity of water added is about twice the stoichiometric amount required for the hydration reaction. There are many designs of equipment but technically the hydrator consists of pairs of contra - rotating screw paddles, which vigorously agitate the lime in the presence of water. A strong exothermic reaction takes place generating 1140 kJ per kg CaO. the average residence time of the solids in the main reactor is about 15 minutes. The heat release causes a vigorous boiling action, which creates a partially fluidized bed.

The main variables which affect the quality of slaked lime are:

a) Reactivity (to water) of the quicklime.
b) Particle size distribution of the quicklime.
c) Amount and quality of water used.
d) Temperature of the water.
e) The pattern of addition of the lime and water.
f) Agitation during slaking.

Storage

Quicklime is preferably stored in dry conditions, Great care is exercised to ensure that water is excluded from the lime, as hydration liberates heat and causes expansion, both of which could be dangerous.

Hydrated lime absorbs carbon dioxide from the atmosphere, forming calcium carbonate and water. Therefore, it is best stored in dry draft - free conditions. Hydrate bagged in paper sacks is preferably stored under cover to avoid deterioration by moisture, and re - carbonation of the hydrated lime. When “Big bags” are used, they are also best stored under cover to prevent any damage.

Experimental

Sampling of lime products may be required for quality control, for the assessment of the suitability of a product, or for monitoring compliance with a specification. Testing may be done to assess a product’s mechanical, physical or chemical properties. In this study, limestone samples, quicklime and slaked lime were analyzed. (12)

Preparing of samples

Mix 1.0 g of sample with 2.0 g of fusion mixture in a platinum crucible and cover the mixture with a thin layer of the fusion mixture. Cover the crucible with a platinum lid and place in furnace at (975±25) ˚C about 30 min. After completion of the fusion remove the crucible from the furnace and cool to room temperature. Then dissolve the fused mixture in a 250 ml beaker with 10 to 15 ml of concentrated hydrochloric acid, and add 1 g of ammonium chloride, 2 to 3 drops of nitric acid. Stir with a glass rod and set the beaker on a steam bath to evaporate the contents.
Then the samples are tested to determine the proportions of the components:

Determination of silicon dioxide SiO_2:

The filtering paper in funnel is taken to the drier to dried and then placed in a platinum crucible and then burned in a benzene stove and then burned in a furnace oven with temperature of 950 c for half an hour then put in desiccators.
Calculations:

$$(SiO_2)\ \% = (w2 - \_w1) * 2 * 100 \qquad (3.1)$$

Where:
W2**:** the weight of the crucible and deposit after burning
W1**:** the weight of the empty crucible
Note:
The filtrate solution that is in the volumetric flask (500 ml) is supplemented by distilled water to the mark and is kept detecting the rest of the other oxides.

3.1.3 Determination of calcium oxide (CaO):

Procedure:
50 ml of the solution were taken in a beaker (100 ml) then 5 ml of tri - ethyl - amine and 10 ml of NaOH and small amount of the calcium Indictor were added so that the color will be light yellow, mixed well with a magnetic stirrer and titrate against EDTA until the color changes to the red light.

Calculations:

$$(CaO)\ \% = \text{read EDTA} * 2 * F\ (2.8) \ \ldots\ldots\ldots\ (3.2)$$

Where:
F: Factor = 2.8

3.1.4 Determination of Magnesium Oxide (MgO):

Procedure:
50 ml of the same specimen were taken in a beaker and then 5 ml of tri - ethyl - amine and 10 ml of ammonium hydroxide were added and then add the thymol blue detector, the color well be blue and then mixed well with a magnetic, stirrer and titrate against EDTA until the color blue changes to the colorless.
Calculations:

$$(Mg\,O)\% = (\text{current Read EDTA} - \text{Read EDTA of CaO}) * 2 * (2.016) \qquad \ldots.(3.3)$$

3.1.5 Determination of the percentage of Ferric oxide:

Procedure
100Ml of the solution were taken in a beaker and 10 points of Bromo - phenol and Ammonium acetate were add until the color changes to violet then 5 ml of acetic acid and 2 grams of Salicylic acid were added. Mixed well with a magnetic stirrer and then titrate against EDATA until the dark violet color changes to yellow.

Calculations:

$$(Fe_2O_3)\ \% = \text{Read EDTA} * 2 * (1.995) \ \ldots.\ .(3.4)$$

3.1.6 Determination of Aluminum Oxide (AL_2O_3)

Procedure:
Same sample after the identification of the iron Oxide, add to it 10 pints of Pan Indicator and add three points of the copper sulfate and then heated to boiling when the color changes to the red then titrate against EDTA until the red color changes to the yellow color.

Calculation:

$$(Al_2O_3)\ \% = \text{Read EDTA} * 2 * (1.275) \ldots .(3.5)$$

3.1.7 Identification of sulfate percentage (So3):

Procedure:
One gram of the sample were taken then add to it 50 ml of hot distilled water and then 7 ml of hydrochloric acid and then put in the heater until boiling point and filter with a paper of 41 in beaker (400 ml) and then take the sample to heater until the boiling point and add 20 ml of Barium chloride solution and then leave until it is deposited for two hours then filter again with filter paper 44, take the paper to the dryer, weight the empty crucible and put the paper inside it then burnt in the Benzene stove before placed in a carbonite furnace for half - hour in 950˚C then put in desiccator.

Calculation:
$(SO_3)\ \% = (w2 - w1) * 34.3$ ……3.6
Where:
W1**:** The weight of the crucible and deposit after burning.
W2**:** The weight of the empty crucible.

3.1.8 Identification of free calcium Oxide (free lime):

Procedure:
0.5 gram of the sample was taken in flask then 20ml of ethylene glycol were add and then put in a water bath for half hour. Shake the solution every five minute and filter with filter paper grade 40 with vacuum pump take the filtrate solution in conical flask and add three drops of Bromo - cresol - indicator and titrate against hydrochloric acid until the color changes to green yellowish.

Calculation:
Free lime % = Volume of acid *2*HCL correction factor. …. .3.7

3.1.9 Determination of calcium hydroxide (Ca (OH) ₂):

Procedure:
50 ml of the solution were taken in a beaker (100 ml) then 5 ml of tri - ethyl - amine and 10 ml of NaOH and small amount of the calcium Indictor were add, so that the color will be light yellow, mixed well with a magnetic stirrer and titrate against EDTA until the color changes to the red light.

Calculations:

$$(Ca\ (OH)\ 2)\ \% = \text{read EDTA} * 2 * F\ (3.8) \ldots\ldots .3.8$$

Where:
F: Factor = 3.8

4. Result

The samples were tested in White Nile cement factory and the results as follows:

Kasala

T.C	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	L.O.I
92.5	05.22	00.77	00.60	52.64	02.02	39.10

Aljabalain

T.C	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	L.O.I
95	01.56	01.02	00.79	56.28	01.81	39.01

Red sea

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	F.W	C.W
01.76	00.51	00.61	33.60	00.81	00.03	17.62

Quick lime Results

Kassala

Test	Sample Results %
Loss in ignition at 1000˚C % by mass	05.03
Silica as SiO_2 % by mass	20.11
Aluminum as Al_2O_3% by mass	01.13
Ferric as Fe_2O_3 % by mass	00.50
Calcium as CaO % by mass	67.54
Magnesium as MgO % by mass	0.621
Sulfite as SO_3 % by mass	Nil

Al Jabalain:

Test	Sample Results %
Loss in ignition at 1000˚C% by mass	05.03
Silica as SiO_2 % by mass	00.56
Aluminum as Al_2O_3 %by mass	01.30
Ferric as Fe_2O_3 % by mass	00.22
Calcium as CaO % by mass	93.68
Magnesium as MgO % by mass	Nil
Sulfite as SO_3 % by mass	Nil

Slaked lime Results

Kasala

Test	Sample results %
Loss in ignition at 1000˚C % by mass	23.19
Silica asSiO_2 % by mass	12.87
Aluminum as Al_2O_3 %by mass	01.12
Ferric as Fe_2O_3 % by mass	00.41
Calcium hydroxide as $Ca\ (OH)_2$ % by mass	73.48
Magnesium as MgO % by mass	07.14
Sulfite as SO_3 % by mass	Nil

Al Jabalain:

Test	Sample results %
Loss in ignition at 1000˚C % by mass	23.13
Silica asSiO_2 % by mass	00.49
Aluminum as Al_2o_3 % by mass	00.91
Ferric as Fe_2O_3 % by mass	00.11
Calcium hydroxide as $Ca\ (OH)_2$ % by mass	98.80
Magnesium as MgO % by mass	Nil
Sulfite as SO_3 % by mass	Nil

Sample of red sea was excluded because total carbonate is very low, total carbonate should be more than 90%.

Accordingly, it was found the limestone of Al Jabalain is better than limestone of Kasala, because the quality of quick lime and slaked lime is high and silica content is low; Al Jabalain row material was selected.

5. Conclusion

Three samples of limestone were taken from three different places in the Sudan: Aljabalain, Kasala and Red sea. The three samples were analyzed and the Red sea sample was excluded because the percentage of calcium carbonate is low. The other samples were burned in the kiln at temperature 1200°C and analyzed, the result of analysis showed that the limestone of Aljabalain is the best because it contains a high percentage of calcium carbonate.

Quicklime was produced with high quality and slaked lime was produced with a purity of 98 %.

6. Recommendation

Based on the findings in this study, the following is recommended:

1) The lime industry must be taken into consideration.
2) The cost of importing lime has been reduced and people can develop the industry in the future so that the cost is reduced more.
3) Studies should be done to control and reduce carbon dioxide emissions.
4) Intensify efforts and exploration to discover new places for limestone.
5) Utilizing the heat energy generated from the slaking process.

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