

Cement Industry in Sri Lanka

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Abstract— Cement is used as a construction material in Sri Lanka. It is made with calcined lime and clay. Alumina, silica and iron oxide are the main substance of the clay. In Sri Lanka, the demand for cement is high in the building and construction sector. In the beginning, the establishment of the Kankasanthurai cement factory is the first cement factory in Sri Lanka. The purpose of this study is to examine the production process, its economic support, raw material availability, demand, process modification, optimization steps to implement the production process with minimal environmental impact and minimize the environmental pollution by the cement industry.

Index Terms— Cement, Process modification, Environmental impact, Energy optimization.

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1 INTRODUCTION

In Sri Lanka, the cement industry was introduced four decades ago by the state and managed by the state until very recently. Sri Lanka is perhaps the only country in this region, which uses a 100% dry process for manufacturing cement. Puttalam Cement Company Ltd is the only factory that involves cement production from raw material excavation to cement packing in Sri Lanka. The use of cement has long been the basis for the development of society and the welfare of the people for generations. Concrete, which is made from cement, has been the ultimate material for construction. The cement manufacturing process is technology-intensive. The cement industries should recognize its responsibility to manage the environmental impact, due to the manufacturing of its product.

Mainly, there are two types of the cement production process; such as wet process and dry process. The preparation of cement includes mining, crushing, and grinding of raw materials, calcining the materials in a rotary kiln, cooling, mixing the clinker with gypsum and milling and bagging the finished cement. The cement production technologies in use cause extensive power consumption, gas emissions, noise pollution environmental heating and emissions of flue gases (CO_2 , NO_x , SO_2 , and CO) from the kiln and pre-calciner. These are the major sources of environmental pollution in the cement industry to the best possible extent [1].

2 CEMENT MANUFACTURING PROCESS

A cement production plant consists of three major processes such as quarry and raw material preparation, clinker production and cement grinding and distribution [2]. During raw material preparation first, limestone and other raw materials are extracted using drilling and blasting techniques. Afterward, the quarried material is reduced in size in crushers by compression. The limestone, clay and alternative raw materials mixed and homogenized as the first step of the clinker production. The homogenized raw material is preheated before entry into the kiln. Afterward, the raw materials are burned and transformed into clinker minerals at flame temperature up to 2000 Celsius and materials temperature up to 1450 Celsius. Finally, during the cement grinding and distribution process, firstly the cooled clinker is ground with around 5% of gypsum and other

cementitious materials to form the final cement types [2]. The flow diagram of a typical cement manufacturing process is shown in Fig. 1 [3]. Finally produced cement is transported in bags (packages) or as a bulk powder. Table 1 shows the cement manufacturing sub-processes ongoing in Sri Lanka [2].

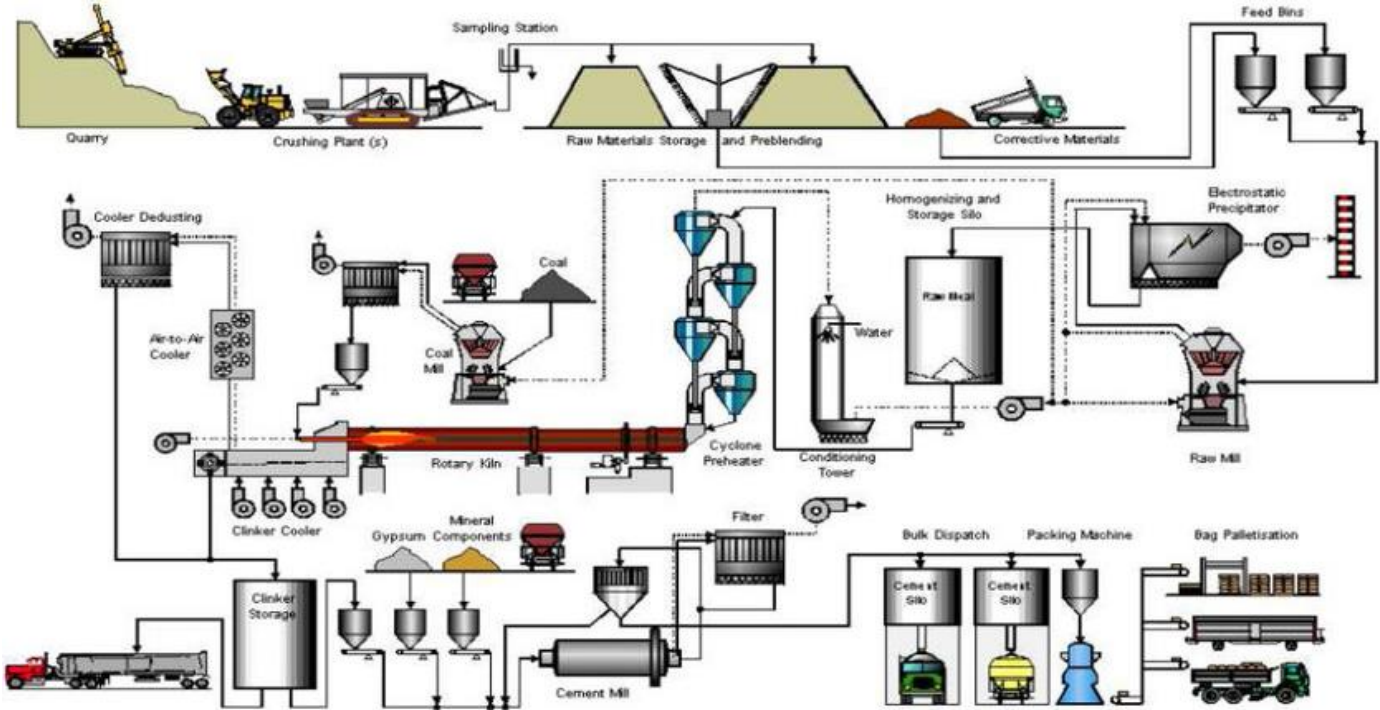


Fig. 1. Cement manufacturing process flow diagram [3]

Table 1. Sri Lanka’s Cement Manufacturing sub processes

Cement production process	sub	Inputs	Outputs
1.Extraction of materials/quarrying limestone	raw	Electricity, explosives and fuel	Extracted limestone, greenhouse gases emission, dust, noise and vibrations.
2.Limestone crushing		Extracted limestone, clay and other additives, electricity.	Crushed limestone, noise, vibrations. GHGs emissions, dust
3.Homogenizing		Crushed limestone, electricity, compressed air	Dust, indirect GHGs emissions due to high electricity usage, noise.
4.Preheating		Homogenized materials, electricity waste heat from kiln	Indirect GHGs emission
5.Burning		Raw material mixture, kiln fuels, electricity	Clinker, direct and indirect GHGs / CO2 emission, cement kiln dust, noise, vibration, heat.
6.Clinker grinding		Clinker, gypsum, cements enhancers. Cement enhancers, electricity	Cement powder, dust, indirect GHGs emission. Chemical containers.
7.Cement packaging and Send		Cement powder, paper bags	Packed cement, dust cement, rejected things.

For the production of cement, naturally occurred minerals and as well as industrial products can be used. Raw materials for this purpose are mineral compounds, containing the main components of cement, lime, silica, alumina, and iron oxide. The two main components are generally limestone and clay. In cement raw materials the lime component is generally represented by an amount of 75%-80%. The main component of clays is formed by hydrous aluminum silicates. Clays are divided into the following mineral groups; the Kaolin group (Kaolinite Dickite Nacrite Halloysite) and the Montmorillonite group (Montmorillonite, Deidellite, Nontronite, Saponite). Chalk is a sedimentary rock, which is formed during the cretaceous period in geological time. Blasting is not required for quarrying chalk and the crushing process can also be omitted. This kind of raw material considerably lowers the cement production costs. Calcium carbonate (CaCO_3) which is widespread in the nature of all geological formations qualifies for the production of cement. The most common forms of Calcium carbonate is very similar to marble, limestone, and chalk [4].

2.1 Sri Lankan Limestone Deposits

Sri Lankan limestone deposits are well spread from Puttalam, Jaffna to Mullaitivu cities over the coastal belt. This limestone region is commonly named as Jaffna limestone region. The Fig.2 shows the limestone deposits of Sri Lanka [5].

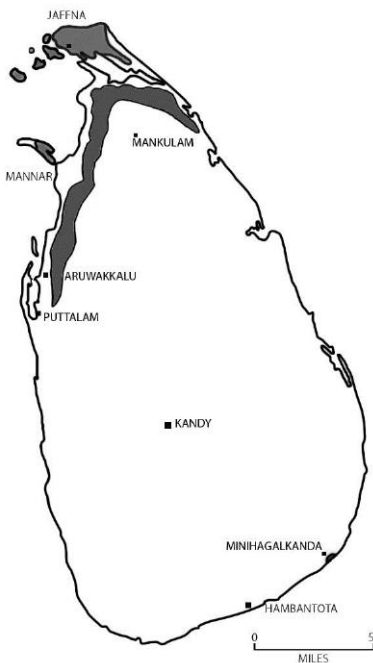


Fig.2. Limestone deposits of Sri Lanka [5]

2.2 Raw Material Transportation

In Sri Lanka limestone, the extracted main raw material is transported using company-owned locomotives and railway. According to the cement industry, the distance between the plant and the quarry is forty-seven kilometers. Other raw materials are transported using outsourced vehicle fleets. Mainly dolomite is from Kandy and Matale area and laterite is sourced from Andigama, in Anamaduwa. Gypsum is received at Colombo ports and it is transported using outsourced vehicle fleets [6].

3 LOCATION FOR CEMENT PLANT

As the common knowledge that in economic motivation is how to maximize profit from capital employed. Location is an irreversible investment, even as the largest capital in the investment itself. The optimum location of an industry depends on demand in relation to supply, availability of raw materials, production cost, distribution cost, managements' regional interest, and government policy concerning regional development [7]. In the cement industry availability of raw materials, fuel and cost for transportation are more significant than the other factors. Table 2 represents the cement plant locations and relevant information on Sri Lanka [8].

Table 2. Cement plant locations in Sri Lanka [8]

Group Name	Company Name	Facility Name	Location
Siam City Cement, PLC(SCCC)Group	INSEE Cement (Lanka) Ltd.	Galle Cement Works	Galle
Siam City Cement, PLC(SCCC)Group	INSEE Cement (Lanka) Ltd.	Puttalam	Puttalam
Siam City Cement, PLC(SCCC)Group	INSEE Cement (Lanka) Ltd.	Ruhuna Cement Plant	Galle
Tokyo Cement Company(Lanka) PLC	Tokyo Cement Company(Lanka) PLC	Trincomalee	Trincomalee

4 ECONOMIC SUPPORT TO THE COUNTRY'S ECONOMY

Concrete is an essential commodity in a built environment, especially in infrastructure development. It is the second most-consumed material after water and it shapes the built environment which resulted in concrete as the most seen man-made material available in the world. Concrete is a material produced by mixing binder - cement, water, and aggregate. The average cement content in concrete is about 15% [5]. This demand made cement as one of the most wanted materials in the current business context due to the increasing construction activities and no successful alternative found to replace cement yet. Boosting economies demand a lot on higher developments in infrastructure mainly in the constructional field. Fig. 3 shows the relationship that the cement production growth pattern for developed and developing economies separately. Also, it indicates the CO₂ release from cement production. Increasing cement growth in developing countries significantly contributed to the increased CO₂ volumes [5].

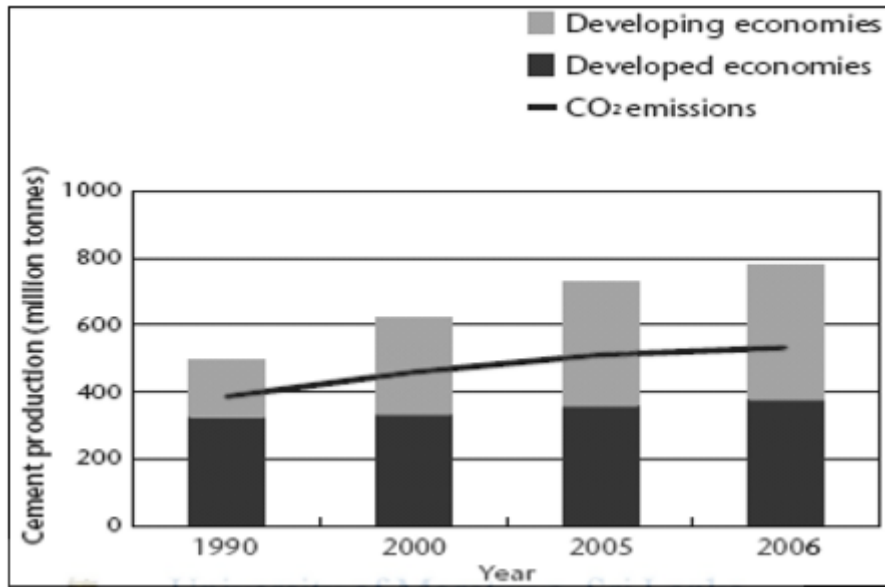


Fig.3. Cement production and accompanying CO₂ emissions [5]

Table.3. cement manufacturing volume data in Sri Lanka 2009-2018[9]

Item	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018 ^(a)
Local Production										
Production Volume, MT '000	1,453	1,740	1,974	2,084	1,910	1,884	2,287	2,695	2,819	2,841
Imports										
Volume, MT '000	1,702	2,012	2,584	3,796	4,123	4,363	4,092	5,299	5,676	5,114
Value, Rs. Mn.	14,042	14,856	22,222	33,337	40,536	41,304	39,372	50,589	53,498	48,386
Imports Price (C.I.F.), Rs. per MT	8,250	7,385	8,599	8,783	9,832	9,468	9,622	9,547	9,425	9,461
Price, Rs. per MT (Annual Avg.)^(b)	11,279	9,855	10,720	13,097	13,787	13,902	13,160	11,734	11,367	12,345

Table 3. shows the recent cement manufacturing volume in Sri Lanka [9]. With the post-war developments and the rapid construction growth, Sri Lanka cement demand also in the rapidly increasing trend as shown in Fig. 3. It is estimated to be consuming about 7.9 million tons of cement per annum (2018) [2]. According to the above Fig.3. data, in 2018 Sri Lanka imports around 66% of its requirement either in the form of cement and clinker with little value addition in Sri Lanka [2]. Sri Lanka imports cement from India, Vietnam, Pakistan, Malaysia, Indonesia, and Thailand. This has pushed the country to become the fourth largest importer of the world and the cement grinding capacity is expected to increase by 14% by 2021. However, nearly 40% of Sri Lanka’s cement demand is still met through local clinker grinding with both locally produced and imported clinker. The high-value addition to the industry, together with considerable employment opportunities within local communities makes local manufacturers a vital facet in the economic development of the country.

5 PROCESS MODIFICATION

Cement industry production is an energetic process and emits substantial large amounts of greenhouse gasses to the environment. Due to some research, it is estimated that the process of cement industry emits 7% of global

manmade carbon dioxide emissions which support global warming. Many efforts have been made to improve the environmental quality of the bottom ash, during its processing or by post-treatment techniques [10]. The technique of co-processing has been employed for introducing alternative fuels and this technique provides:

- Lower cost of production
- Introducing fuel waste from different industrial activities
- Besides contributing to reduction of environmental liabilities
- Generates waste when discarded in inappropriate places

The ecological analysis is done through a comparison between ecological efficiency, pollution indicator and values for CO₂ equivalent from cement industry rate, before and after the adoption of waste reuse [10]. Process modification in the cement industry can be done according to two parts which can reduce the environmental impact of cement production.

- Process plant optimization
- Production process optimization

Some of the expected benefits of the process plant optimization are

- Saving in specific fuel consumption
- Saving in specific electrical energy consumption
- Consistency in plant operation and hence improved run factor
- Improve product quality
- Reduction in maintenance cost

The main sources of carbon dioxide in cement industry are [11]:

- Combustion of fossil fuel
- Limestone calcination

The different suggested solutions for disposal are

- Discharge into natural gas reservoirs or aquifers
- Discharge deep into the ocean or reuse the CO₂ in useful organic compounds

The cement industry process is always among the largest Carbon dioxide emission sources. Almost 57 percent of global CO₂ emission is caused by cement process plants, while 900kg CO₂ is emitted to the atmosphere for producing one ton of cement.

Their strategies of Carbon dioxide reduction including:

- Energy saving
- Carbon separation and storage
- Utilizing alternative materials

Carbon capture and storage (CCS) are also known as an effective way to avoid the release of CO₂. However, economical and technical challenges still pay a remarkable obstacle against implementing such processes in this process plant. As well as alternative materials are the case, utilizing waste-derived fuel (WDF) and industrial by-products instead of conventional fuels and materials result in the significant emission mitigation. Industrial

wastes that can be used as both fuel and raw material simultaneously mitigate emissions in cement plants and landfills [12].

Plant optimization is a well-known approach to achieve the same quality and quantity of cement products with the lowest possible amount of fuel consumption, pollution emission, and operation costs. Optimization strategies should be implemented to minimize fuel consumption, pollution emissions and eventually to minimize expenses production of the cement industry. The pre-heater tower which is consisted of cyclones and ducts is highly important to preheat raw materials and to prepare them for calcination reactions. A well-structured and regular maintenance program can highly result in plant performance improvement as well as fuel consumption and emission reduction. Among difference maintenance programs, preventive maintenance is one of the most effective and valuable parts which leads to a more efficient production process. Regular maintenance can significantly contribute to energy-saving and consequently in curbing CO₂ emissions [12].

There is a huge amount of heat release to the environment as waste heat. It has done some experiments to reduce and upgrade the heat releasing to the environment. Waste heat utilization has been studied with the CO₂ capture plant [13].

6 WASTE GENERATION BY CEMENT INDUSTRY

In cement manufacturing process, mainly solid waste include clinker production and spoil rocks, which are removed from the raw materials during the raw material preparation.

- Solid waste
- Waste water
- Waste air

6.1 Solid Waste

Environmental pollution by the Cement industry previously has been studied. It has suggested several modifications to be done in the cement industry to reduce the waste generation [14].

6.1.1. Kiln Dust

The fine-grained, solid, highly alkaline waste removed from cement kiln exhaust gas by air pollution control devices is Cement kiln. The reason for that, much of the kiln dust is un-reacted raw materials, large amounts of it can and recycled back into the production process. Some kiln dust is reused directly, while some require treatment before reuse. Kiln dust not returned to the production process is typically disposed of in land-based disposal units (i.e. landfills, waste piles, or surface impoundments), although some are also sold for beneficial reuse.

6.1.2 Fly Ash

The use of fly ash in Portland cement concrete has many advantages. It improves concrete performance in both the fresh state and hardened state. Fly ash use in concrete improves the working ability of plastic concrete, and the strength and durability of hardened concrete. When fly ash is added to concrete, the amount of Portland cement may be reduced.

6.1.3 Cement Dust

Emission of dust from cement factories has been increased alarmingly due to the expansion of more cement plants to meet the requirement of cement materials for construction sector. Increasing concentration of cement dust pollutants causes invisible injuries like the progressive decline in the physiological process such as photosynthetic ability and respiration rate of leaves.

6.2 Waste Water

Water is used at several stages during the production process. In only some cases, water is used for the preparation of raw materials, in the clinker burning and cooling process. Such as the cooling of gases, as well as in the technological process for slurry production. In the cement industry wastewater is not a big environmental problem. Because, in general, cement production does not generate effluent. In cement production, water is only used in small quantities in both the dry and semi-dry process (Ex; for cleaning process).

6.3 Waste Air

Actually, waste air is the main waste which is generated from the cement industry. Air pollutant emissions are presented for the process of this production, including other process steps. Such as storage and handling.

What are the types of air pollutants which are generated from the cement industry?

- Oxides of nitrogen (NO_x) and other nitrogen compounds
- Sulphur dioxide (SO_2) and other Sulphur compounds dust
- Total organic compounds (TOC) including volatile organic compound (VOC)
- Metals and their compounds
- Hydrogen fluoride (HF)
- Hydrogen chloride (HCL)
- Carbon monoxide (CO)

Not mentioned on the list, but carbon dioxide is also the main air pollutants of the cement productions. The main constituents of the flue gases exit from a cement kiln are nitrogen released from the combustion air, Carbon dioxide from calcination of CaCO_3 and combustion of fuel.

7 ENVIRONMENTAL POLLUTION BY WASTE OF CEMENT INDUSTRY

7.1 Air Pollution

The major air pollutants released by cement production can be categorized as,

- Methane
- Fume
- Dust
- Nitrogen oxide
- Sulphur oxide
- Carbon dioxide
- Carbon oxide

Which are responsible for global warming potential. Which can harm the environment and also harmful to human health through respiration.

- Sulphur oxide (SO_x)

Sulfur is essentially present all together cement stuff. The combustion of fuel containing Sulphur and oxidization of Sulphur in stuff forms the Sulphur oxides. Emitted Sulphur oxides react with vapor and different chemicals in the atmosphere within the presence of daylight to make acid. The acid fashioned are often washed away by rain and snow that is known as acid rain. It decreases agricultural productivity and will increase the death of plants. It additionally causes metastasis downside known as respiratory disease.

- Carbon dioxide and CO

Cement industries are the key supply of CO₂ emissions. It's calculable that fifty of total CO₂ emission is from cement industries. CO₂ is made from fuel combustion and decarbonization of raw materials. Alternative supply of CO₂ emissions is fuel sort used, transportation and energy from execution to dispose of. CO₂ is accountable for the international climate amendment and totally different metabolic process illness and asthma attack on the soul. CO causes health impacts by reducing chemical element delivery to organic structure and causes an effect on vas and the central system. Carbon dioxide capture technologies have been studies for the cement industry. The main drawback of the capture technologies is the high amount of regeneration energy requirement in the boiler [15, 16].

- Nitrogen oxide (NO_x)

NO_x is formed due to thermal oxidation which happens in the temperature range of 1200-1600 °C. The family of nitrogen oxides includes nitrogen dioxide, nitric acid, nitric oxides, nitrates, and nitrous oxides. Because of the variety of family compounds nitrogen oxide is responsible for a wide range of effects. Nitrogen oxide reacts with water to form various acidic compounds. These acidic compounds acidify lakes and water sources which creates difficulty for the survival of aquatic animals. It is also responsible for global temperature increase high range. The smog is created by Nitrogen oxide when breathed causes respiratory diseases. It creates difficulty in breathing and chronic lung diseases. It may ultimately result in cancer diseases [13].

7.2 Solid Waste

In cement producing chiefly solid waste embody clinker production and spoil rocks, that area unit far away from the raw materials throughout the raw meal preparation. Oven mud and ash from station additionally enclosed in solid waste. Alternative waste is generated from plant maintenance like used oil and metal scrap. Principally these wastes area unit disposed of by lowland outside that causes many respiratory organs and inhale drawbacks [17]. Currently most of the plant's mistreatment ash for cement production. Lime waste from the crushing department could also be employed in clinker production or sulfate treatment once re-crushing. Typically in-depth mining activities bit the water level and should contaminate spring water. Deposit of mud in open space cause land degradation and additionally deposits over plant leaves. Currently most of the plants' mistreatment ash for cement production. The mud collected from completely different pollution dominant devices is reused in the producing method [18].

7.3 Waste Water

In cement industries, water is employed just for the cooling operation of the producing method. The waste material with high pH and suspended solids could also be generated in some operations [19]. Usually, the water used for cooling purposes can be recycled and reused within the system. Screening and for suspended solid reduction is completed by mistreatment subsiding basin and clarifier. Water treated from wastewater treatment plants ought to use for inexperienced belt development[20]. This inexperienced belt conjointly helps in minimizing sound pollution. At lime mining site and cement plants, contaminated streams of rainwater ought to be directed to the wastewater treatment plant and may use for the process. Storm-water flowing through pet-coke, coal, and waste matter stockpiles exposed to the out-of-doors might become contaminated. Rainwater ought to be shielded from contacting from coal depot clinker and lime and ash enclosure to forestall contamination by covering the enclosure and may collect at some tank for additional use in mud suppression system at the plant. If storm-water will contact the storage yard than it should indicate the presence of high value of sulfate in soil and cyanogenic metals like atomic number 30, Lead and Cr within the mud and high TDS value in water [20].

8 EFFICIENCY IMPROVEMENTS

The addition of industrial outgrowth and wastes to cement in the production process or to concrete mixtures essentially improves the overall energy balance and efficiency of the manufacturing process. However, it is not the only path in which energy efficiency can be improved. Over the decagon, the cement production process has changed from one using a slurry process to mix the raw meal integrant to a totally dry process in the contemporary plants. Furthermore, the addition of pre-heaters to the older, long kilns has enlarged heat recovery and caused an increase in production quantity. This all has lead to a decrease in the energy enforced for the production of cement [21]. This in itself has made a great contribution to the sustainability of cement production. Even now up to 6 pre-heaters and a pre calciner are considered standard equipment in a modern cement plant. Another modern advancement in improving energy efficiency is the practice of heat recovery to bring out electricity. Drain heat from cement kilns have traditionally being used to dry coal or raw materials, but since the 1980's different boiler and heat exchanger merger have been installed at cement plants worldwide to generate steam and afterward electricity from it. This concept is, of course, coming off at the back end of the manufacturing process. Some companies advertising on the internet claim that up to 30% of accumulation can be achieved in the electricity expenditure of a cement plant if waste heat recovery systems are installed to develop on-site electricity [21].

9 ENERGY OPTIMIZATION

To optimize the long term performance of a cement manufacturing unit requires a plant full automation strategy. Reducing energy demand in all areas must be connected with the search for the optimal operating point that is dependable with productivity and quality targets, and in line with enforced environmental emission limits. Helping cement producers achieve their operational objectives is Knowledge Manager (KM) [20]. Knowledge Manager can process the largest amount of data and provide with right information at the right time, used by Expert Optimizer (EO) to model the process and to identify the best possible way of running the plant at all times [22].

9.1 Knowledge Manager Using for Energy Monitoring (KM)

Knowledge manager contributes the solutions and advanced tools necessary to facilitate the collection, organization, and circulation of combined production, quality, and energy information throughout a plant organization by web-based articles, trends, and graphs. On a particular page, all relevant key performance indexes for the process are calculated and displayed. If an operator wants to enlarge production and at the same time maximize the usage of alternative fuels, the Knowledge Manager provides the information for appropriate analysis to establish what is and is not possible. KM can be adapted and developed to meet each company's specific requirements. It extremely simplifies cement production management by covering processing related functions such as reporting, Process operations checking and reporting Material storage management, Energy and emission reporting. With KM and Production tracking analyzing the influences that process criterion have on production capacity, product quality, energy consumption, and emission levels is now simple than ever. It made with energy indexes, production-related data, process variability, and run-time quality parameters to produce comprehensive operation and trends and production reports. The trends results and quality of reports in the superior utilization of equipment, inventories, energy, and capacities.

9.2 Expert Optimizer Using for Thermal Energy Savings (EO)

The cement manufacturing process is an energy-intensive process. The main stage in this process is the conversion of raw materials (CaCO_3 , clay or shale) into clinker in the kiln [4]. Preheat the raw materials by using kiln exhaust gases before they enter the kiln. Further heating up to about 1 500 °C, takes place in the kiln's burning area where the materials are moderately melted and react to form clinker. Consecutive processing is needed to convert the clinker to cement. Cramped amounts of gypsum (CaSO_4) are added and lastly, the mixture is ground to a fine powder [23]. Conventional control of a cement kiln needs the services of practiced operators who make frequent adjustments to the set points established by the controller and must constantly interpret process conditions. This task is onerous enough but it is made even problematic by complicated responses, interactions between individual process variables and time delays.

10 CONCLUSION

Cement is one of the most usable product in the world for construction industry. The main process flow is discussed with the emissions, environmental impacts and necessary improvements to reduce the energy consumption and emissions. The carbon dioxide, nitrogen oxide, sulphur dioxide and dust are the main contributors for air pollution. The available reduction technologies are discussed with further required modifications to improve and optimize the production process.

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