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ENERGY AUDIT OF CEMENT INDUSTRY: A REVIEW

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Abstract - *The Indian Cement Industry is the second largest producer of cement in the world after People's Republic of China, Republic of India holds the second place with 277 MTPA (as of 2011). India being short on fossil fuels, it calls for an Energy Conservation. Indian cement industry is considered as an energy efficient industry by switching onto dry process, but still it has a long way to go.*

Under the Energy Conservation Act, 2001 Cement industry along with other 8 sectors are termed as designated customers. The EC Act, 2001 started PAT, in order to further accelerate as well as incentivize energy efficiency. The Indian cement industry consumes 14.5 million MTOE which accounts to 6.26% of total energy consumption (231.6 million MTOE) of all eight sectors. By the end of the first PAT cycle, the energy savings of 0.816 million MTOE/year is expected to be achieved, which is around 12% of total national energy saving targets projected under PAT.

The project report is mainly focused on the major energy consuming areas like the rotary kiln. The project report also deals with the material balance of rotary kiln and energy balance of major ancillary equipment and chemical reaction. It also gives a wide range of alternative technologies that can be implemented for energy conservation.

Keywords: **Cement, Energy conservation, PAT cycle, rotary kiln, ancillary**

1. INTRODUCTION

Cement is a universal name for powdered materials which at the beginning have plastic flow when mixed with water or any other liquid which forms a solid structure in several hours with varying strength and bonding properties which continue to improve with time. The most common is Portland cement which is a basis of number of cement products. Specifically, Portland cement is defined as finely ground calcium aluminates and silicates of varying composition which hydrates when mixed with water to form rigid continuous structure with a good compressive strength.

Status of Cement Industry in India: India is the second largest producer of cement in the world. No wonder, India's cement industry is a vital part of its economy, providing employment to more than a million people. Since it was de-regularized in 1982, the Indian cement industry has attracted more and more investments, both from Indian investors along with foreign investors. India has a huge future scope development in the infrastructure and construction sector, and this largely benefits the cement industry. Some of the recent initiatives taken by the government such as the development of 98 smart cities are expected to provide a major development to the sector. Expecting such developments in the country which are aided by suitable government foreign policies, few of the foreign players such as Lafarge-Holcim, Heidelberg Cement, and Vicat have invested in the country in the recent years. The availability of the raw materials for making cement, such as limestone and coal is one of the major factors for the growth of this sector.

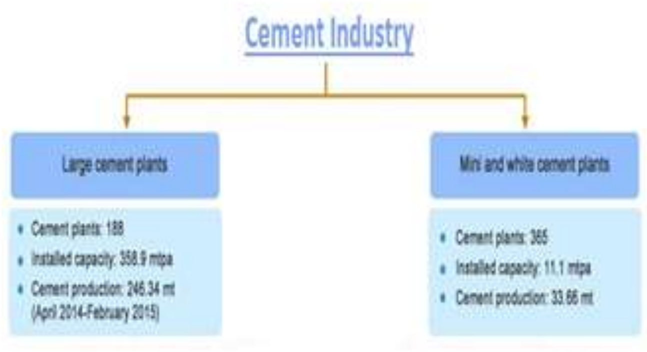

Figure 1: Classification of Cement Industry

2. CEMENT AND ITS VARIETIES [1]

2.1. Portland Cement

Portland cement is the product obtained by pulverizing clinker which mainly consists of calcium silicate to which calcium sulphate is added in a small proportion and inter-ground to the required fineness. Often mineral admixture like fly-ash, slag etc, are also added and inter-ground. At times chemical admixtures like air-entraining agents and other performance improved are also mixed to impart certain special properties. Portland cement reacts with water and hydrates to form cementitious compound that possess setting and hardening characteristics.

In any chemical reaction, features of interest are the changes in the matter, changes in energy and its speed of reaction. This is also true for cement hydration. Portland cement itself is not cementing material, but its hydration products have the cementing action. The hydration process is exothermic. Heat released is important as its same times helps and at other times has advanced effect. Knowledge of reaction fed is important because it influences the setting time and hardening process of all application where Portland cement is used.

The first patent for Portland cement was obtained in 1824 by ***Joseph Aspdin***, an ***English mason***. This cement was first used in the early 19th century in England. It was called Portland cement because its hydration product resembled building stone from the Isle of Portland off the British coast. The first use of Portland cement was in masonry mortars. As the confidence level increased, its various applications increased. Mortar mixed with stone chips [aggregates] resulted in its application of concrete. In the 19th century, Portland cement was rapidly being used in reinforced concrete applications. The second half of the 20th century witnessed a phenomenal growth in its applications. In India, Portland cement made a humble beginning in 1913. Today, India is the second largest producer of cement in the world with a consumption of around 145.48 million metric tons per annum.

Table 1: Grades of Portland cement

IS Number	Grades
269	33 Grade ordinary
8112	43 Grade ordinary
12269	53 Grade ordinary
8041	Rapid Hardening
455	Slag
1489[Part 1]	Pozzolana [fly-ash based]
1489[Part 2]	Pozzolana [Calcined clay]
8043	Hydrophobic
12600	Low Heat
12300	Sulphate Resistant

2.2. Pozzolana

Portland Pozzolana Cement is a kind of Blended Cement which is produced by either inter-grinding of OPC clinker along with gypsum and pozzolanic materials in specified proportions or grinding the OPC clinker, gypsum and pozzolanic materials are separately and thoroughly blended in specified proportions. History suggests that, cementing materials have played a vital role and were used widely in the ancient world. There is one such kind of powder from which natural causes produces astonishing results. When this powder is mixed with lime and rubble, it enhances the strength of buildings of other kinds and when piers are constructed of it in the sea, they set hard under-water.

Table 2: Types of Pozzolana cement

Type	Name
I	Normal
IA	Normal-Air Entraining
II	Moderate Sulphate Resistance
IIA	Moderate Sulphate Resistance-Air Entraining
III	High Early Strength
IIIA	High Early Strength-Air Entraining
IV	Low Heat of Hydration
V	High Sulphate Resistance

Pozzolana Cement is ideally suited for following purposes:

- ❖ Hydraulic structures, mass concreting works.
- ❖ Marine structures.
- ❖ Masonry mortars and plastering.
- ❖ Under aggressive conditions and all other applications where OPC is used.

2.3. High Alumina

High Alumina Cement (HAC, also known as calcium aluminate cement [CAC] or aluminous cement) is composed of calcium aluminates, unlike Portland cement which is composed of calcium silicates. High Alumina Cement is manufactured by grinding clinkers of calcining bauxite (it's an aluminium ore) and ordinary lime. In which the amount of alumina content should not be any lesser than 32% and it should maintain the ratio by weight of alumina to the lime between 0.85 to 1.30. Currently this high alumina cement is more popular in countries like United States and United Kingdom.

The first documentation of isolated calcium aluminate species dates to 1848 when Ebelman reacted alumina with marble. In 1846, Vicat had developed Portland cements with higher alumina contents for sulphate resistance. Both French and English patents were granted to Bied in 1908 and 1909 for the manufacture of calcium aluminate cement. Bied used bauxite and lime as raw materials fired them together in a cupola furnace. Because of their relatively high cost, calcium aluminate

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cements are used in various restricted applications where performance achieved justifies the costs: -

- In construction concretes, rapid strength development is required, even at low temperatures.
- As a protective liner to prevent microbial corrosion such as in sewer infrastructure.
- High strength requirement at elevated temperatures in refractory concretes.
- In sewer networks which offer high resistance to biogenic sulfide corrosion.

3. CAPACITY [4]

India is the 2nd largest producer in the world with a total installed capacity of 277.46 million MTPA as on 31st December 2010. The industry has seen a growth rate in the installed capacity of more than 10-20% over the past 3 years (2007 to 2010). There are 165 large plants in India and around 365 mini cement plants operated by 32 cement manufacturing companies. These large plants itself perform 96% of the total production. Indian cement industry comprises of both private and public sector ownership, but it is dominated by private

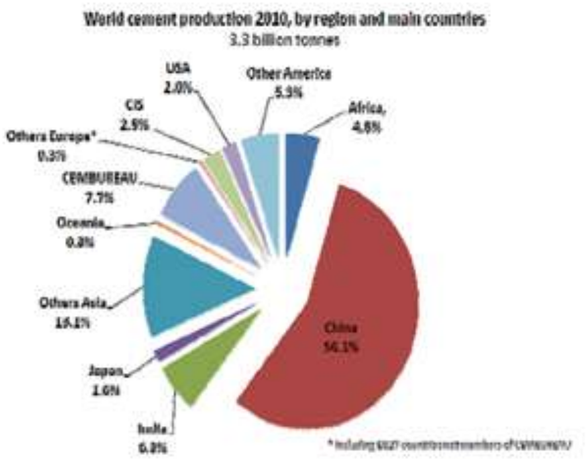

Figure 2: World Cement Productions [7]

companies. The private sector cement companies constitute 97% of total the cement production in the country.

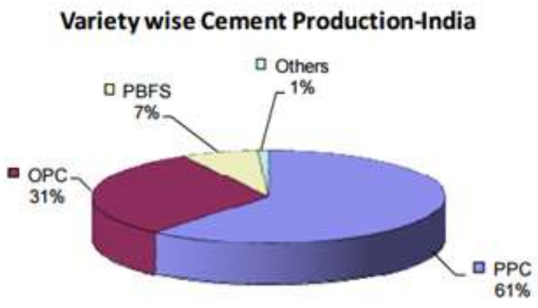

Figure 3: Variety wise Cement Production

As on 31st December 2010 the total installed capacity in India constitutes to 277.46 million MTPA with a production of 207.84 million MTPA from 165 cement plants. The table 1.3 shows the breakdown of the production capacity among the different cement plants.

Table 3: Capacity of Indian Cement Industry

Sl. No	Company	Capacity (million MTPA)
1	Ultratech Cement	48.75
2	ACC Cement	30.21
3	Ambuja Cement Limited	25.00
4	Jaypee Cement	17.15
5	India Cements Limited	15.85
6	Madras Cements Limited	12.72
7	J K Cement Limited	12.27
8	Shree Cement Limited	12.00
9	Dalmia Cement Bharat Limited	9.00
10	Chettinad Cement Corporation Limited	8.20
11	Century Cement	7.80
12	Kesroram Cement & Vasavadatta Cement	7.25
13	Lafarge India Private Limited	6.55
14	Others	64.72
	Total	277.46

India produces variety of cement such as Ordinary Portland cement (OPC), Portland Pozzolana cement (PPC), Portland Blast Furnace Slag cement (PBFSC), white cement and specialized cement. Cement production in India is as per the Bureau of Indian Standards (BIS) specifications and the quality of cement produced is comparable with the best in the world. The figure 1.3 shows the various types of cement manufactured in India as on December 2010.

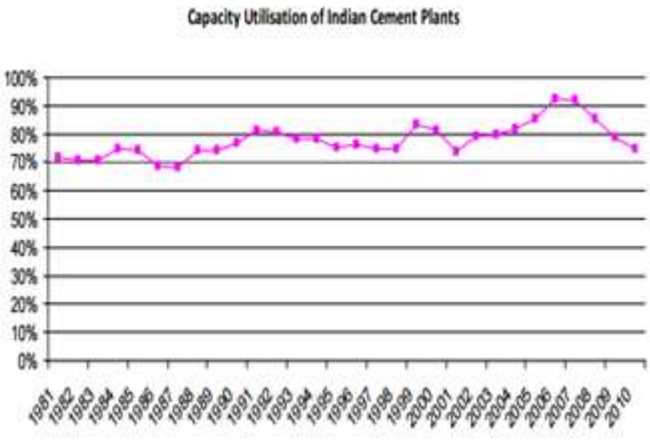

Figure 4: Capacity Utilization 0f Indian Cement Plants [7]

4. PROCESS DESCRIPTION [4]

4.1. Raw Materials Used for Cement Manufacturing:

Limestone: - Contains predominantly calcium carbonate ($CaCO_3$) and to use in cement manufacture, it should have 41-43% lime (CaO) minimum. In cement manufacture it is a major raw material and its usage would be 90- 92%.

Clay: - It contains more of silica (SiO_2) and its usage should be 2 to 3% in cement manufacture.

Bauxite: - It contains alumina (Al_2O_3) and its usage should be 2 to 3% in cement manufacture.

Iron Ore: - It contains mainly iron oxide (Fe_2O_3) and its usage should be 1 to 2% in cement manufacture. The raw materials mix composition would be 90-92% limestone, 2-3% clay,1-2% Bauxite, 1-2% Iron ore in cement making.

4.2. MANUFACTURING OF CEMENT

Methods of cement manufacturing:

Wet process - grinding and mixing of the raw materials in the existence of water. The moisture content in the raw materials is high.

Dry process - grinding and mixing of the raw materials is done in their dry state. The raw materials being too hard (solid), do not disintegrate by water

4.3. General Description of Wet Process

Wet process: - When chalk is used, it is finely broken up and dispersed in water in a wash-mill. The clay is also broken up and mixed with water, which is usually done in a similar wash-mill. The two mixtures are now pumped to mix in predetermined proportions and pass through a series of screens. The cement slurry then flows into the storage tanks.

When **limestone** is used, it must be blasted, then crushed, usually in two progressively smaller crushers (initial and secondary crushers), and then fed into a ball mill with the clay dispersed in water. The resultant slurry is pumped into storage tanks. From here onwards, the process is the same regardless of the original nature of the raw materials.

The slurry is a liquid of creamy form, with water content of between 33 and 50%, and only a small fraction of material – about 2% - larger than a 90 µm (sieve No. 170).

The slurry is mixed mechanically in the storage tanks, and the sedimentation of the suspended solids that are being prevented by bubbling compressed air pumped from bottom of the tanks.

The slurry is analyzed chemically to check the achievement of the required chemical composition, and if necessary, the composition of the constituents is changed to attain the required chemical composition.

Finally, the slurry with the desired lime content passes into the rotary kiln, which is a large refractory-lined steel cylinder with a diameter of up to 8m, sometimes as long as 230 m, which is slightly inclined to the slurry, which is fed in at the upper end while pulverized coal (oil or natural gas also might be used as a fuel) is blown in by an air blast at the lower end of the kiln, where the temperature reaches about 1450 ^{0}C.

As the slurry moves down the kiln, it encounters a progressively higher temperature. Initially, the water is driven off and COR 2R is liberated. Further, the dry material undergoes a series of chemical reactions which then, in the hottest part of the kiln, about 20 to 30% of the material becomes liquid, and lime, silica and alumina recombine. The mass then forms into balls, 3 to 25 mm in diameter, known as clinker. The clinker drops into coolers.

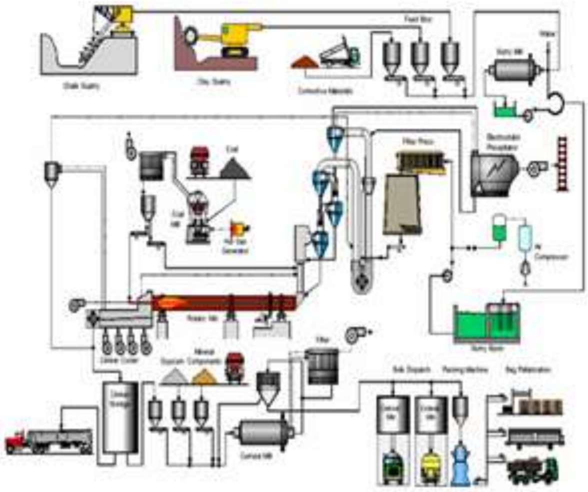

Figure 5: Wet Process [4]

4.4. General Description of Dry Process

The raw materials are crushed and fed in the proper proportions into a grinding mill, where they are dried and reduced in size to a fine powder. The dry powder, called raw meal, is then moved to a blending silo, and adjustments are made in the proportions of the materials required for the manufacture of cement. To obtain a uniform mixture, the raw meal is blended in the silo, usually by means of compressed air. The blended meal is sieved and fed into a rotating dish called a granulator, water weighing about 12% of the meal being added at the same time. In this manner, hard pellets about 15 mm in diameter are formed. The pellets are baked hard in a pre-heating grate by means of hot gases from the kiln. The pellets then enter the kiln, and subsequence operations are the same as in the wet process of manufacture.

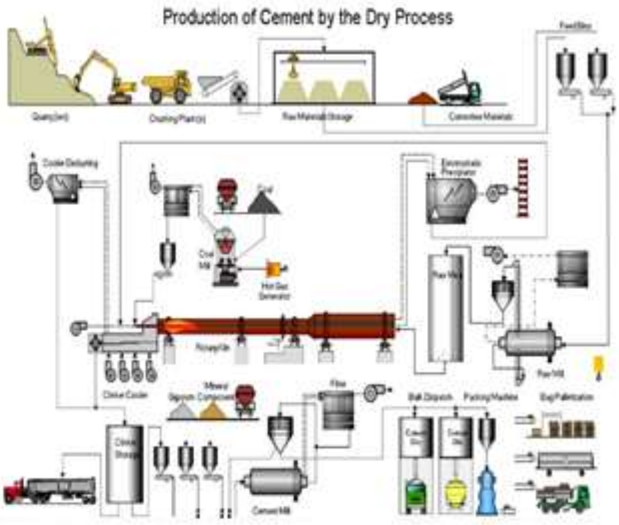

Figure 6: Dry Process [4]

Table 4: Comparison of Wet and Dry Process [4]

Wet Process	Dry Process
-Moisture content of the slurry is 35-50%	- Moisture content of the pellets is 12%
-Size of the kiln needed to manufacture the cement is bigger	-Size of the kiln needed to manufacture the cement is smaller
-The amount of heat required is higher, so the required fuel amount is higher	- The amount of heat required is lower, so the required fuel amount is lower
-Less economically	-More economically
-The raw materials can be mix easily, so a better homogeneous material can be obtained	- Difficult to control the mixing of raw materials process, so it is difficult to obtain homogeneous material
-The machinery and equipment do not need much maintenance	-The machinery and equipment need more maintenance

4. NEED FOR ENERGY CONSERVATION IN INDIAN CEMENT INDUSTRY

The cement industry is an energy-intensive industry together with steel, paper and petrochemical industries. The energy cost in Portland cement production cost is 20 to 31%. If the energy cost is reduced, the manufacturing cost is lowered, resulting in increasing the company's profits. For producing a ton of cement requires about 4.7 million BTU of energy, equivalent to about 400 pounds of coal and generates a nearly a ton of CO_2. Given its high emissions and critical importance to society, cement is an obvious place to look to reduce greenhouse emission.

Ninety percent or more of fuel is consumed for clinker burning. About 40% of electric power is consumed for finish grinding, and a little under 30% each is consumed by the raw material process and the clinker burning process. The finish grinding process mainly consumes electric power for the mill, and the clinker burning process mainly for the fan. The raw material grinding process consumes a large volume of power for the mill and fan. The Japanese cement production process is mostly occupied by SP and NSP kilns and coal is used as fuel, so that the ratio of electric power consumption by the clinker burning process is high. In a plant mainly using a wet process kiln, the finish grinding process consumes power in a larger quantity than the afore mentioned example. In such a case, energy conservation measures shall be taken by focusing on the clinker burning process for the fuel consumption and on the finish grinding process for the electric power consumption.

Indian cement industry is one of the highly energy intensive industry which has a robust growth trajectory over the past decade. Indian cement industry is the 2nd largest producer of cement in the world with a total capacity of 277.46 million MTPA. The per-capita consumption of cement has increased from 28 kg in 1980-81 to 176 kg in 2010, led by the growth in sectors like real estate and construction. Economic growth is contingent upon the growth of cement industry. Consumption of cement is taken to be an indicator of economic development. The greater the infrastructure growth of a country, greater will be the consumption of cement. The Ministry of Power (MoP) has notified industrial units and other establishments consuming energy more than the threshold in 9 sectors in March 2007 as Designated Consumers. Designated Consumers, as notified under the Energy Conservation Act, 2001, account for 25% of the national gross domestic product (GDP) and about 45% of commercial energy use in India. In order to further accelerate as well as incentivize energy efficiency, the Perform Achieve and Trade (PAT) mechanism has been designed. PAT is a market-based mechanism to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings that could be traded. In the first PAT cycle 8 sectors are covered, namely Thermal Power Plants, Fertilizer, Cement, Pulp and Paper, Textiles, Chloro-Alkali, Iron & Steel and Aluminium. The threshold limit of 30,000 MTOE has been defined in PAT for cement sector, and 85 nos. of designated consumers have been identified from various States.

The Indian cement industry consumes 14.5 million MTOE which accounts to 6.26% of total energy consumption (231.6 million MTOE) of all eight sectors. By the end of the first PAT cycle, the energy savings of 0.816 million MTOE /year is expected to be achieved, which is around 12% of total national energy saving targets projected under PAT.

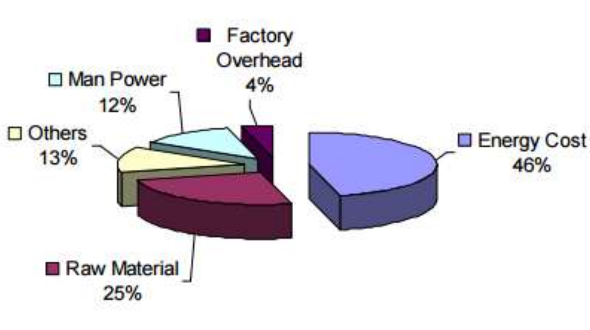

Figure 7: Break-up of Manufacturing Cost [7]

5.1. Electrical Energy

Modern cement plants on an average consume about 65-75 kWh of Electrical energy14 for producing one ton of cement. Cement plant requires electrical energy to run its Mill drives, Fans, Conveyors, Packers and for Lighting systems. Kiln and mills are major electrical power consuming areas of the cement plant. In fact, they are consuming about 60 % of total electrical energy requirement. When it comes to old plants due to the old technologies and some inherent barriers the energy consumption will be in the range of 80-100 kWh per ton of cement. The section wise electrical energy consumption is shown in the graph below.

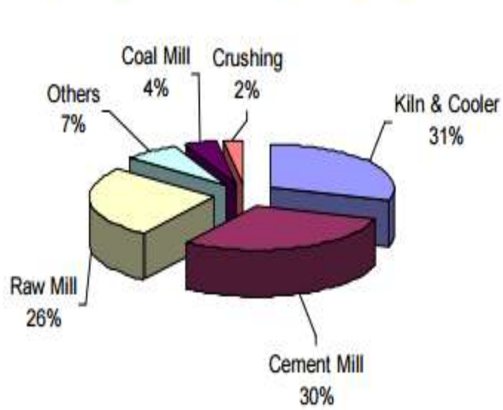

Figure 8: Break-up of Electrical Energy Consumption [7]

Indian cement industry has a total installed capacity of 2430.64MW of coal fired captive power plants. On an average 50-55% of the Indian cement plants has its share of power from the captive power plant. Cement industry has also explored the additional revenue which they can get by exporting the excess produced power to the grid. Indian cement industry has taken a good initiative in setting up renewable energy sources such as wind power to offset its part of the energy consumption from the grid and its own captive power plant. As on 31st December 2010 the Indian Cement industry has an installed wind power capacity of 256.25MW. Government of India has also introduced the Renewable Energy Certificate (REC) mechanism, a market-based instrument policy to promote renewable energy and facilitate renewable energy purchase obligations amongst various stakeholders. RECs are applicable to those companies which are connected to grid and exporting power.

5.2. Thermal Energy

On an average, Indian cement plants require 723 kcal of thermal energy for producing one kg of clinker. The major use of thermal energy is in the kiln and precalciner systems. Thermal energy is needed for the raw meal processing specifically for converting the raw mix to Clinker. Clinker production is the most energy-concentrated stage in cement production. The number of stages in the pre-heater system has a major bearing on the thermal energy consumption in Kiln system. Continuous technological upgrading and assimilation of latest technologies have been steady in the cement industry. Today, 98% of the plants use dry process technology compared to 6% in 1960. Indian cement industry has always been a trend setter for adopting the best available energy efficient technologies. The best thermal and electrical energy consumption presently achieved in India is 663 kcal/kg clinker and 59 kWh/T cement which are comparable to the best figures of 650 kcal/kg clinker and 65kWh/T cement in a developed country like Japan. The specific energy consumption of the Indian Cement Plants has been reducing with continuous up-gradation of technologies and the change in process technologies. The table given below shows the progressive reduction in specific energy consumption by Indian cement industry.

Table 5: Thermal Energy [7]

Parameter	**Year**				
	1950 - 1960	1970s	1980s	1990s	Post 2000
Heat Consumption (Kcal/kg Clinker)	1300 - 1600	900-1000	800-900	650-750	650-750
Power Consumption (kwh/T of Cement	115-130	110-125	105-115	95-105	80-100

5. ENERGY EFFICIENT TECHNOLOGIES IN CEMENT INDUSTRY

6.1. Energy Efficiency Technologies and Measures [8]

Opportunities exist within Indian. Cement plants to improve energy efficiency while maintaining or enhancing productivity. Improving energy efficiency at a cement plant should be approached from several directions. First, plants use energy for equipment such as motors, pumps, and compressors. These important components require regular maintenance, good operation and replacement, when necessary. Thus, a critical element of plant energy management involves the efficient control of crosscutting equipment that powers the production process of a plant. A second and equally important area is the proper and efficient operation of the process. Process optimization and ensuring the most efficient technology is in place is a key to realizing energy savings in a plant's operation. Finally, throughout a plant, there are many processes simultaneously. Fine-tuning their efficiency is necessary to ensure energy savings are realized. If a corporation owns more than one plant, energy management can be more complex than just considering the needs of one. A corporate energy management program helps to ensure energy efficiency is achieved across the company's plants. Whether for a single plant or for an entire corporation, establishing a strong organizational energy management framework is important to implement energy efficiency measures effectively. Several technologies and measures exist that can reduce the energy intensity (i.e. the electricity or fuel consumption per unit of output) of the various process stages of cement production. This section provides more detailed estimates on the technologies and measures, their costs, and potential for implementation in India.

Improving energy efficiency should be approached from several directions. A strong, corporate-wide energy management program is essential. Crosscutting equipment and technologies such as compressed air and motors, common to most plants and manufacturing industries, including cement, present well documented opportunities for improvement. Equally important, the production process can be fine-tuned to produce even greater savings. Below are some measures concerning these and other general crosscutting utilities that apply to the cement industry.

Although technological changes in equipment conserve energy, changes in staff behavior and attitude can also have a great impact. Energy efficiency training programs can help a company's staff incorporate energy efficiency practices into their day-to-day work routines. Personnel at all levels should be aware of energy use and company objectives for energy efficiency improvement. Often such information is acquired by lower-level managers but neither passed up to higher-level management nor passed down to staff. Energy efficiency programs with regular feedback on staff behavior, such as reward systems, have had the best results. Though changes in staff behavior (such as switching off lights or closing windows and doors) often save only small amounts of energy at one time, taken continuously over longer periods they can have a much greater effect than more costly technological improvements.

Establishing formal management structures and systems for managing energy that focus on continuous improvement are important strategies for helping companies manage energy use and implement energy efficiency measures. The BEE's ENERGY STAR program has developed a framework for energy management based on the observed best practices of leading companies. Other management frameworks, such as ISO 14001, can be used to ensure better organizational management of energy. One ENERGY STAR partner noted that using energy management programs in combination with the ISO 14001 program has had a greater impact on conserving energy at its plants than any other strategy.

Improving energy efficiency in glass manufacturing should be approached from several directions. A strong, corporate-wide energy management program is essential. Ideally, such a program would include facility, operations, environmental, health, and safety, and management personnel. Energy efficiency improvements to cross-cutting technologies, such as the use of energy-efficient motors and the optimization of compressed air systems, present well-documented opportunities for energy savings. Optimizing system design and operations, such as maximizing process waste heat recovery, can also lead to significant reductions in energy use. In addition, production processes can often be fine-tuned to produce similar savings.

6.2. ENERGY MANAGEMENT PROGRAMS

Changing how energy is managed by implementing an organization wide energy management program is one of the most successful and cost-effective ways to bring about energy efficiency improvements. Energy efficiency does not happen on its own. A strong energy management program is required to create a foundation for positive change and to provide guidance for managing energy throughout an organization. Energy management programs also help to ensure that energy efficiency improvements do not just happen on a one-time basis, but rather are continuously identified and implemented in an ongoing process of continuous improvement. Furthermore, without the backing of a sound energy management program, energy efficiency improvements might not reach their full potential due to lack of a systems perspective and/or proper maintenance and follow-up. In companies without a clear program in place, opportunities for improvement may be known but may not be promoted or implemented because of organizational barriers. These barriers may include a lack of communication among plants, a poor understanding of how to create support for an energy efficiency project, limited finances, poor accountability for measures, or organizational inertia to changes from the status quo. Even when energy is a significant cost, many companies still lack a strong commitment to improve energy management.

6.3. ENERGY MONITORING SYSTEMS

The use of energy monitoring and process control systems can play an important role in energy management and in reducing energy use. These may include sub metering, monitoring, and control systems. They can reduce the time required to perform complex tasks, often improve product and data quality and consistency, and optimize process operations. Typically, energy and cost savings are around 5% or more for many industrial applications of process control systems. These savings apply to plants without updated process control systems; many Indian. Plants may already have modern process control systems in place to improve energy efficiency.

6.4. PROCESS CONTROL & MANAGEMENT SYSTEMS [10]

Kilns. Heat from the kiln may be lost through non-optimal process conditions or process management. Automated computer control systems may help to optimize the combustion process and conditions. Improved process control will also help to improve the product quality and grinding ability, e.g. reactivity and hardness of the produced clinker, which may lead to more efficient clinker grinding. In cement plants across the world, different systems are used, marketed by different manufacturers. Most modern systems use so-called 'fuzzy logic' or expert control, or rule-based control strategies. Expert control systems do not use a modeled process to control process conditions, but try to simulate the best human operator, using information from various stages in the process.

6.4.1. KILN COMBUSTION SYSTEM IMPROVEMENTS

Fuel combustion systems in kilns can be contributors to kiln inefficiencies with such problems as poorly adjusted firing, incomplete fuel burn-out with high CO formation, and combustion with excess air Improved combustion systems aim to optimize the shape of the flame, the mixing of combustion air and fuel and reducing the use of excess air. Various approaches have been developed. One technique developed in the U.K. for flame control resulted in fuel savings of 2-10% depending on the kiln type discusses advancements from combustion technology that improve combustion using better kiln control.

6.4.2. THERMAL ENERGY EFFICIENCY IMPROVEMENT OPPORTUNITIES [8]

Kiln and preheater system in Indian cement industry has achieved very high levels of technology adoption and energy efficiency levels. With significantly higher productivity levels and installation of latest energy efficiency and automation control devices, these systems are operating at one of the best performance measures in the world. India's modern cement plant is equipped with six stage (or five stage in certain clusters having higher moisture levels in limestone) preheater with in-line or separate-line calciner (depending on the rated kiln output), kilns with volumetric loading of about 5-6.5 tpd/cu.m and advanced automation systems. Continuous

Emission Monitoring Systems (CEMS) are also being increasingly adopted in new as well as existing kilns.

6.4.3. INSTALLATION OF HIGH EFFICIENCY CLINKER COOLERS

The Indian cement industry, over the last several years, has increasingly adopted

Reciprocating grate coolers with great success. While rotary coolers have been completely phased out, several installations with planetary coolers are still in vogue. With more than 50% of cement produced from kilns less than 10 years old, reciprocating grate coolers have become common practice in the industry today, with cooler loading of about 45–50 TPD/m² of cooler area. A conventional grate cooler operates at a recuperation efficiency of 50-65%, depending upon the mechanical condition and process operation of the coolers. This corresponds to a heat loss of about 120-150 kCal/kg of clinker from the cooler. Quite many cement kilns in India, as a result higher capacity utilization operates at significantly higher cooler loading range than rated, with a range of 50-65 TPD/m² of cooler area in-spite of the design range of 45-50 TPD/m². This has also resulted in increased heat losses from the kiln.

The reciprocating cooler has under gone significant design development and the latest generation coolers has better clinker properties with significantly lower exit gas and clinker temperatures. As a direct consequence, secondary and tertiary air temperatures offered by latest generation coolers have also increased to about 1250°C and 1000°C respectively. The cooling air requirements of such coolers have also gradually reduced to about 2.2-2.4 kg/kg of clinker. The total heat loss of latest generation clinker coolers is less than 100kCal/kg of clinker and has a recuperation efficiency of 75-80%.

6.4.4. INSTALLATION OF CROSS BELT ANALYZERS

Sampling of crushed limestone or raw meal (input to the kiln) is essential to maintain stockpile quality and control chemistry of raw mix, thereby maintaining homogeneous clinker composition to meet quality requirements. Currently, several plants are adopting conventional sampling and quality control methods where sampling of a fixed quantity of material is collected at frequent intervals. These samples are analyzed for its chemical composition through X-ray techniques. Collection of samples and its analysis results in time delay for correction and manual error in analysis. This in turn, affects clinker quantity and increases energy consumption. Cross belt analyzers analyze the chemical properties of the materials instantaneously and direct corrective actions much quicker compared to conventional sampling and quality control methods. Cross Belt Analyzers (CBA) can be installed either in upstream of the stock pile or before the raw mill. Former option helps to track the cumulative chemistry of the pile thus allowing the operator to direct haul trucks to various sections of the quarry to maintain target elemental composition of the pile. Installation of CBA before the raw mill can monitor the chemistry of the raw mix and automatically trigger adjustment in proportions of reclaimed stockpile and take corrective actions in varying the quantity of additives. The cross-belt analyzers are needed in cases of heterogeneous deposits of limestone is present or the limestone is received from more than one mines

6. ELECTRICAL ENERGY EFFICIENCY IMPROVEMENT OPPORTUNITIES [10]

7.1. Installation of High Efficiency Respirators

Separators are used in material grinding for the purpose of separating the fine particles from the coarse material coming out from the ball mill thus increasing its grinding efficiency. The fine particles are collected as product while the coarse particles are sent back to the mill for further grinding. A good separator should ensure that the stream of coarse material general referred as reject should contain very little fine particles as possible (less than 10-15% retained over 45-micron sieve) and the stream of fine material contain very low quantities of coarse material. An efficient separator improves the mill performance by avoiding the over grinding of the material and thereby reduces the grinding power consumption. By efficiently separating the coarse particles from the fine particles, it maintains the required product fineness, avoids over-grinding, thereby saving mill power consumption. High-efficiency separator / classifier improve the grain size distribution of the finished cement and reduce grinding power requirements. The high separation efficiency results in higher proportion of classifier fines which results in decline of the number of circulations of the mill feed and hence the throughput rises by up to 10 -15%. This result in reduction of the specific energy demand compared to grinding circuits with standard separators. High efficiency separators contribute to the energy demand for grinding with about 5 to 8%.

7.2. INCREASE THE PPC PRODUCTION / PERCENTAGE ADDITION OF FLY-ASH IN PPC MANUFACTURING

Clinker when ground and mixed with 4-5% gypsum, reacts with water and hardens. Several constituents are available for mixing with clinker for production of blended cement. Clinker when mixed with fly ash (from thermal power plants) will produce Portland Pozzolana Cement (PPC). Increased use of blending materials in clinker has direct impact on reduction in clinker factor (% of clinker content by mass in cement) in cement thereby reducing fuel combustion and reduced limestone calcinations. Fly ash conforming to standard IS: 3812-1 2003 can be used (up to 35% maximum) in the manufacture of PPC as per IS: 1489-1 1991. The role of fly ash in PPC is attributed to the pozzolanic action leading to a contribution to strength development. Studies carried out on the Indian fly ash samples have indicated that the range of glass content varies between 15 and 45% and the Lime Reactivity (LR) between 2.0 and 7.0 mpa. The fine fraction of fly ash below 45 microns is a major portion and contributes predominantly to the performance of PPC. This aspect of fly ash is very important with a view to enhance the % of use of fly ash in PPC and concrete and needs further thorough and systematic investigations to arrive at adoptable methodologies of using finer fly ash at higher levels. The quality of the clinker and suitable and adequate admixture addition will improve the fly ash absorption.

7.3. INSTALLATION OF PRE-GRINDER ALONG WITH BALL MILL FOR MATERIAL

- **Grinding: -**

Material grinding is the largest electrical energy consumer in cement manufacture. Ball mills are used for grinding application of raw materials containing moderate moisture content. The size of the balls in the mill chamber determines the degree of fineness of the finish's product. In a ball mill majority of the grinding takes place by attrition force produced by the cascading effect rather than the coarse grinding happening by impact in the first chamber. By design ball mills are efficient in fine grinding than coarse grinding.

Installation of Roller press in the upstream of ball mill can avoid the inefficient coarse grinding from ball mill, reduce and maintain the feed size to mill hence make the system more efficient. The roller press grinds the material by immense pressure and thus gives a much finer product to the ball mill. Roller press can produce the product with size less a micron. Reduced feed size of the material to the ball mill results in reduced power consumption for grinding needs. Many plants have installed the roller press along with the ball mills and achieved reduction in specific energy consumption. Installation of roller press along with separator can result in reduction of power consumption in the range of 25-30%. Installation of roller crusher along with the ball mills can also reduce the power consumption for grinding the ball mills. Roller crushers are used for primary crushing or secondary crushing of easily fractured materials such as lime stone or clinker. Lumps of materials are reduced to sizes ranging from one third to one fifth of the original size. Crushing is achieved by passing the material between rollers. Typically, the installation of roller crusher can result in reduction of power consumption in the range of 5-10%.

7. ENERGY AUDIT PROCEDURE [12]

An energy audit includes more than just taking measurements. For the measurements to be useful, they must be part of a systematic procedure to identify and implement the most cost-effective energy-conservation programs. Energy audits involve gathering system information, measuring energy use, developing conservation strategies, choosing the most cost-effective plan, implementing changes, and verifying results. Also, a proactive facility continues improving energy efficiency by repeating this process at regular intervals.

8.1. PREPLANNING

Energy audit preplanning begins with making a commitment to energy conservation. Multiple levels of a business must be involved and dedicated to making the entire audit process a priority. The initial goals of the preplanning phase are to establish the audit team members, decide on the scope of the audit, develop a timeline of tasks to be completed, and assign team member responsibilities. The preplanning process typically lasts between a few weeks and a few months, depending on the size of the facility and scope of the audit.

8.2. AUDIT TEAMS

An audit team is formed from the personnel of different departments. A relatively small group, such as three to five employees, is tasked with the bulk of audit work. The group usually consists of maintenance personnel, who are the most familiar with the building systems and equipment. See Figure 2. However, other team members coordinate certain supporting tasks. Accountants gather and organize data from utility bills. Production staffers coordinate audit activities with employee and operating schedules. High-level managers are closely involved so that necessary decisions can be made quickly in order to facilitate audit tasks.

Figure 9: Audit Teams [12]

8.3. AUDIT-SCOPE

The audit team must decide on the initial scope of the audit. This includes which systems will be investigated and the depth of the investigations. Facility maintenance personnel may already suspect where significant energy wastes are and what tests will be required to quantify them. This information is usually the basis for deciding on the type of audit. Audit scope can always be expanded later if initial results lead to deeper testing. However, it is helpful to establish early the criteria for allowing the scope to be expanded along with how other phases of the process will be affected.

8.4. BASELINE DATA GATHERING [13]

An energy audit relies heavily on comparisons between expected energy use and actual use. Actual energy use is quantified as baseline and measured data. Baseline data is data that represents a normal operating state and is used as a point of reference for future changes. Most measured data are gathered later during an audit investigation, but baseline data is gathered primarily from existing documents. The most common sources of baseline energy use data are utility bills. Billing information should cover at least the preceding 12 months. However, gathering information from over a few years may better represent any seasonal or long-term trends. Other documentation that is useful when planning an energy audit or analyzing results includes equipment specifications, manufacturer recommendations for testing equipment, and maintenance records. Audit team members may also want to interview personnel who work on or near major equipment about their observations and suggestions.

8.5. PLANT PROFILE

Preliminary information is used to create a plant profile. This is a snapshot view of the facility including square footage, energy expenditures, significant loads, control system set points, and other basic facts.

8. CONDUCTING THE ENERGY AUDIT

The auditing portion of an energy audit consists of two phases. First, the core members of the audit team investigate and then help prepare an audit report. The supporting members of the audit team are also involved in preparing the audit report. Outside contractors may be involved in any phase for their expertise or specialized tools.

9.1. AUDIT INVESTIGATIONS

An audit investigation involves the inspection of each system within the scope of the audit. It traces from the source of energy or the resource to each point of use. A variety of test instruments is used extensively during the investigation to identify energy waste and other abnormal conditions. The audit assesses the efficiency, physical condition, and operating profile of the equipment, including the duty cycle, load changes, and controls. Resources are available from equipment or test instrument manufacturers that provide guidelines of how to take measurements and recognize potential energy waste issues. The length of this phase may last from several days to several weeks, depending on the size of the facility and whether data logging extended is needed. Collected data is recorded for later analysis.

9.2. AUDIT REPORTS

The second phase of an audit is the preparation of the audit report. On the report, the completed investigation is summarized, and the findings are presented in an organized and prioritized format. The financial cost of each instance of wasted energy is calculated, based on the audit measurements. Related multiple issues may be grouped together for analysis. For example, a series of three leaks in a compressed air system is causing the compressor to operate approximately 50% more than expected. The cost of the extra electricity consumed is estimated from the electrical measurements of the audit and the rate data from the billing information. This is the amount that would be saved if the leaks were eliminated.

For each energy problem, one or more possible remedies are listed, along with their estimated total costs. Total costs must include any financial impact of completing the project, including equipment expenses, installation or repair labor, employee training, and process downtime. The financial analysis portion presents the ROI estimates for each option. For example, the repair of the compressed air distribution system to eliminate the leaks would incur a certain cost in parts and labor, which is compared to the estimated cost savings to determine the payback period. Each project is usually listed in the report in order of payback period, unless there are other factors that affect its importance, such as safety. This prioritization provides a simple way for decision makers to evaluate the relative cost-effectiveness of the recommendations.

9.3. IMPLEMENTING CHANGES

Based on the results outlined in the audit report, decision makers evaluate the recommended projects against budget and other constraints. Some or all the recommendations are approved, and an action plan is developed to facilitate the implementation. Team members are assigned responsibilities to initiate and monitor each project, ensure that it is completed according to the recommendation, and consult with the audit team if changes to the project plan become necessary. Project planning should also include preparation for how the success of the project will be measured.

9.4. VERIFYING AND SUSTAINING RESULTS [13]

As energy conservation projects are completed, the results should be measured to determine whether the goals of the project were achieved. Audit-type measurements should be conducted again to verify the expected energy savings and confirm that there were no negative effects. It is highly recommended to install permanent monitoring equipment on the largest or most critical loads to continuously measure energy consumption.

Maintenance programs should be adjusted as needed to help sustain the energy savings. This typically involves improving preventive and predictive maintenance activities, along with supporting prompt and effective troubleshooting and repairs in the event of a failure.

Complete follow-up audits should be conducted at periodic intervals to verify expected energy use and identify long term trends toward inefficiency. Simple walk-through audits may be conducted monthly or quarterly, and more thorough audits conducted at longer intervals. The audit process then begins again with preplanning, forming a continuous cycle of efficiency improvement.

9. CONCLUSIONS

In this review, the different forms of energy patterns that are consumed in a cement industry are discussed along with the manufacturing process of cement and how the energy auditing method that is implemented in the industry. This report also discusses the different ways in which energy can be saved in different sectors of the cement industry.

Further study shows that majority of the cement industries use dry process for the manufacturing of cement as it is more efficient in comparison with wet process.

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