



# CEMENT & BUILDING MATERIALS REVIEW

Published by : Arab Union for Cement and Building Materials No.85 September 2021



## 25<sup>th</sup> Arab International Cement & Building Materials Conference and Exhibition

**(AICCE25)**

Riyadh, Saudi Arabia

**2022**

المؤتمر والمعرض العربي الدولي الخامس والعشرون لصناعة الإسمنت ومواد البناء

الرياض، المملكة العربية السعودية

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# Cement and Building Materials Review

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# CEMENT PLANT OPERATIONS & IMPORTANCE OF PROCESS OPTIMIZATION

By : RAJNI KANT MANAWAT

## ABSTRACT

Setting up the most advanced cement manufacturing facility does not, on its own, guarantee profitable operations. In order to ensure its profitability and make it maximum cost efficient, cement manufacturing facility constantly requires sound operational practices besides advanced technological design. All the stakeholders are striving hard to ensure best operational practices but this approach is a continuous exercise. Undoubtedly, Cement Industries are facing couple of challenges. But other than saving costs, we have to be mindful about being energy efficient and using a robust and reliable solution to ensure best operational practices in the cement plants. To offset the challenges in the area of energy management and ensure energy efficiency in the cement industry, the Companies are employing cutting edge technology solutions and also emphasising on operations audit for a diagnostic review to see what's wrong or what kind of improvement can be done with production/operations.

## INTRODUCTION

In this regard, plant operational studies are an efficient tool to identify the areas of energy conservation & plant optimisation. The most important of those areas are PROCESS CONTROL and PROCESS OPTIMISATION. Other potential areas could include preventive maintenance, raw-mix & fuel-mix optimization, dust emission reduction etc. The studies have also identified the potentials for increasing production & reduction in energy consumption and in planning their investment priorities for their plant's modernisation.

There is a regular practice in cement plants to ask a process engineer to explore the "big picture" in production/operations and also for a diagnostic review to see what's wrong or what kind of improvement can be done in production/operations.

In this paper, author has shared his experiences as he remained involved in the field of PLANT OPERATIONS and has specifically dealt with process optimisation for enhancement of plant productivity and savings in energy consumption through Plant Operations Audit.

## WHAT IS PLANT OPERATIONS AUDIT & ITS OBJECTIVE?

It is an effective way for enhancing the productivity and minimising energy consumption. It is the first step in conducting a general/objective assessment of a production/operations area. It is also known by many other names, such as diagnostic review, general survey, operations exam, etc. It can be done as a stand-alone project, but is usually done as a part of a larger project, such as reducing costs or improving productivity. The methodology is based on a judicious evaluation of the current aspects that control the operating environment. The following are the objectives of a comprehensive plant operations audit:

- Optimization of the output.
- Reduction in Specific Energy Consumption.
- Trouble shooting of mechanical, electrical and process systems.
- Dust abatement.
- Quality assurance.

## WHEN OPERATIONS AUDIT SHOULD BE DONE

An OPERATIONS AUDIT should be done whenever important changes of a general nature are required. These important changes may include; a plant-wide cost reduction effort, the installation of a productivity program, thermal energy efficiency program, electrical energy efficiency program, chemistry and operations strategy, changes in the management information

system, the introduction of new product, new plant acquisitions, prior to relocations of plants etc.

### TOOLS REQUIRED TO CONDUCT OPERATIONS AUDIT

A variety of tools are used by Process Engineer to conduct the audit are as under: -

1. Conducting audit as a project, with a written objective, defined tasks, expected deliverables, listing of work steps and its schedule.
2. Conducting meaningful interviews at all level of the organization and drawing clear, concise findings and conclusions in document.
3. Gathering data necessary for the conduct of audit, analysing data and also obtain realistic data from key departments.
4. Undertaking operations tour and related field trips for gathering important general information with product flow charts, equipment location drawings.
5. Recording observations and answers to key questions during operation tours and related visits for confirmation and verification at a later date.
6. Obtaining Organisation charts, job descriptions, budget plans, financial statements, operations records, and written operating procedures during conduct of the audit.

### STEPS FOR PROCESS AUDITS

#### A. HISTORICAL EVALUATION

Plant operating and shutdown data need to be collected for the past two or more years. The reasons, duration and frequency to identify the causes in order of severity of the stops are analysed and their classification:

- Process/operation
- Mechanical
- Electrical
- Instrumentation
- Refractory

Plant performance is also analysed by department. Often, the best performance of a department does not occur at the same time as the best performance of the plant as a whole. If we choose the best throughput times for each department and make them occur at the same time, the throughput of the plant will show a significantly higher level of efficiency. Attempts are being made to make them happen at the same time, which is not an unrealistic goal, as the departments had indeed done so at that level in the past.

Through a systematic approach, all departments are made to function at the highest possible level, increasing overall equipment effectiveness.

#### B. BENCHMARK

Modern dry-process cement plants with an efficient grinding and pyro processing system, typically consume less than 680-700 KCal/Kg-Clk of thermal energy and 65-75 KWH/Mt of electrical energy. Older plants with inefficient systems, combined with operational and maintenance failure, tend to have much higher energy consumption. Based on the specific plant conditions and requirements, a general benchmarking is conducted to set goals. Plant audits evaluate the performance of a cement plant against the appropriate benchmark. After a detailed evaluation, recommendations are made for optimizing the plant at three levels of capital investment:

- Level 1: no or very little capital investment, making adjustments to operating protocols and improving maintenance.
- Level 2: minor capital investments, with ROI within 24 months.
- Level 3: Large capital investments, with ROI within of 3 to 5 years.

#### C. THERMAL ENERGY

- A successful thermal energy management program requires energy auditing as its one of the important procedures. The possible approaches of heat recovery from some major heat loss sources by making a detailed analysis of kiln, raw mill, coal mill and grate cooler. To improve the production process, increase the productivity, decrease energy consumption of the plant.
- Thermal energy is related to the pyro processing system. For a clinker production of 1 million tons per year, the savings of 10 kcal/kg-cl would result in an annual savings of approximately \$92,000.
- $(1,000,000 \text{ TPY} * 1,000 \text{ kg/year} * 10 \text{ kcal/year} * \$ 60/\text{t-coal}$
- $(6,500 \text{ kcal/kg of coal}/1,000 \text{ t of coal})$
- Another significant advantage in most cases is that the reduction in heat consumption can be used to increase production.

Potential savings can also be derived from:

- Cooler optimization
- Stop leakages
- Optimization of operational strategy

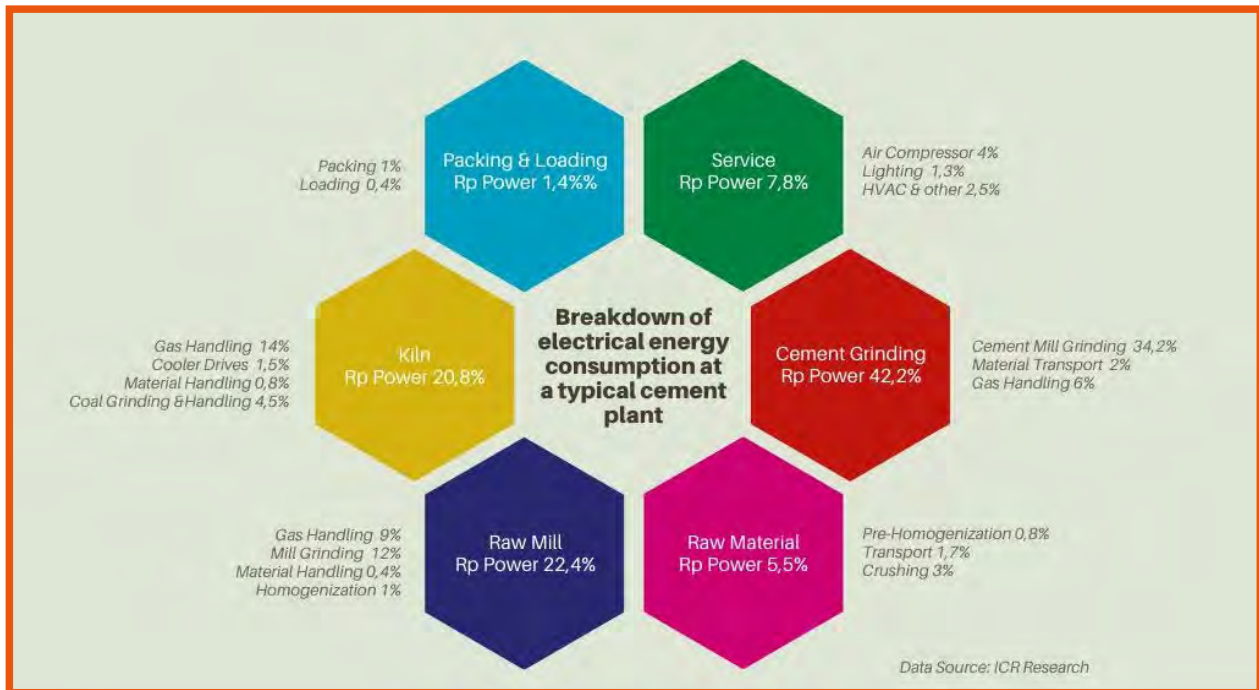
**D. ELECTRICAL ENERGY**

The main aim of the energy audit is to provide an accurate account of energy consumption and energy use analysis of different components and to reveal the detailed information needed for determining the possible opportunities for energy conservation.

- Large fans and mill units are the main consumers of electrical energy.
  - o Fans: Fan power is linked to specific heat consumption and many operating parameters.

to achieve the maximum productivity. A few examples of the optimisation measures are given below:

1. The false air infiltration in the system to be kept as low as possible.
2. The required operating parameters like temperature, pressure, etc. have to be maintained for a particular equipment. For example, at the outlet of the raw mill, the material temperature is to be maintained as 90-100oC.
3. In case of cement production in ball mills with



Optimizing these parameters will help reduce the fan’s power consumption.

- Mills: In the case of ball mills, optimizing the mill load and maintaining the internal parts of the mill will minimize energy consumption. As for the vertical roller mills, the inspection of the internal parts of the mill and the separator, and the adjustments in the operation will bring improvements, both in energy consumption and in increased production.

**E. CHEMISTRY AND OPERATIONS STRATEGY**

Problems related to clinker quality are addressed by evaluating chemistry and operating parameters.

**WHAT SHOULD BE PLANT OPERATIONAL APPROACH: OUR PHILOSOPHY**

Plant operational approach is another way of cost reduction. The objective is to optimise the operations

high fineness i.e. more than 350 m<sup>2</sup> / kg, suitable grinding aid may be used.

4. A kiln burner operation may be optimised to achieve the desired shape and intensity of flame with the minimum primary air.
5. Kiln shell cooling fans may be operated if the kiln shell temperature exceeds a certain value say 250oC.
6. The clinker cooler operation should be optimised to achieve the maximum secondary air temperature and tertiary air temperature.
7. Idle run of the equipment must be prevented particularly during start up and stoppage periods. Similarly, the feed interruptions/ reductions must be avoided. Plant operational audit may also be carried out on regular basis.
8. Optimisation of the output, Reduction in specific energy consumption
9. Trouble shooting in electrical, mechanical and process systems, Dust abatement, Quality

- assurance.
10. Change of Mindset from conventional practices & Full utilization of Equipment's Capacity.
  11. Enhance mining life by using low grades mines/ Mines reject and high MgO
  12. Enhance the Pond-ash consumption by employing Furnace.
  13. AFR usage implementation, waste available from nearby regions.

### WHY SHOULD CEMENT PLANTS ADOPT MODERN PROCESSING TECHNIQUES

The main objective for adopting the modern processing techniques in cement production are as follows: Improve capacity utilisation, Energy savings, Improved environment, use of waste heat, use of by-products, wastes, alternative raw materials and fuels, Meeting market requirements in terms of quality and types of cement i.e., Quality assurance, lowering investment cost and thereby reducing cost of production.

#### CASE STUDY:

ABC CEMENT LIMITED, established a Greenfield cement plant. It has a Single kiln equipped with 6 stages preheater and pre-calciner supplied by FLS. The kiln is 4.35 m ID x 67 m long with rated capacity of 4500 TPD clinker.

The plant is commissioned in the FY2010. The captive mines for this plant are spread in the area of 502 Hectares. Geologically, the different litho-units encountered in the area are black cotton soil, clay/Gravel, light grey to dark grey limestone, greenish siliceous limestone and quartzite. Limestone of grey and dark grey coloured, fine grained, massive and bedded in nature occur in folded and deformed structure. The upper beds are fractured and joints which are the avenues for the intrusion of the Gravel /clay and soil from the overlying layer are frequent. Gravel mixed with smaller size limestone is difficult to separate at mine face in mechanized mining operations. Increasing the production of the kiln will bring in the additional capacity as well as the saving in thermal and electrical energy consumption. The production capacity of the kiln can be maximized by optimizing the Specific Volumetric Loading of kiln. These in-turn depend on the burnability of the raw-mix which is in turn the function of chemical, mineralogical composition, the fineness and homogeneity of the raw mix.

The kiln of Dia. & Length resp. 4.35m X 67m is designed at 4500TPD and with effective volume of 821 M3 however a sustainable volumetric loading of 08 TPD/M3 would result in a maximum achievable clinker production of 6500 TPD. The kiln parameters and evaluation of the kiln tube is tabulated in the table 1. From this data it is clear that there is potential to increase the kiln output by increasing the filling, specific volumetric loading and thermal loading. This can be achievable by improving the raw mix burnability, consistency and also need to be examined the capacity of the feeding equipment, grinding mills and other ancillary equipment to unleash the possible output from the kiln.

The study is conducted and modifications were implemented to achieve the maximum potential output through optimization of raw meal and streamlining of operational process parameters.

#### PROBLEM

Whenever plant operating more than 4500 TPD leading to disturbance in the kiln, dust circulation, snowman formation, flushing of clinker from Kiln-cooler system and ultimately leading to non-compliance of the clinker quality. The yellow core is observed in the clinker continuously. The coating formation in the kiln burning zone is also observed.

#### STUDIES CONDUCTED

##### 1. Optical Microscopic Studies of the Limestone Samples from Different Benches of Mines

To understand the mineralogy, grain size of constituent minerals, groundmass and their micro-structures of limestone samples have been collected from all the benches of the quarry. A detailed optical microscopic study of the samples has been carried out at laboratory.

The major mineral constituents, accessory minerals, shape of the mineral grains and their occurrence along with groundmass, modal composition of minerals and granulometric analysis have been carried out for all the samples collected. Numerous micro veins of euhedral calcite grains are present in the rock. The major mineral constituents are calcite, quartz and dolomite. Accessory mineral is iron oxide. Traces of mica are also observed. Subhedral calcite grains with rounded grain margins are uniformly distributed in the rock. Margins of calcite grains are partially stained. Subhedral to anhedral quartz grains are also uniformly distributed in the rock. Grain size variations in the quartz are too

**PROCESS OPTIMIZATION**

<b>Table 1: Kiln Parameters and evaluation</b>		
<b>KILN PARAMETERS</b>	<b>DESIGNED VALUE</b>	<b>ACHIEVED VALUE</b>
CAPACITY(TPD)	4500	6568
LENGTH (M)	67	
DIA (M)	4.35	
SPEED (RPM)	5.5	
SLOPE (%)	4	
SPECIFIC HEAT CONSUMPTION (K CAL/ KG CLINKER)	710	700
BRICK THICKNESS (M)	0.2	
<b>KILN EVALUATION</b>		
KILN L/D	15.4	
EFFECTIVE VOLUME (M3)	821	
EFFECTIVE CROSS-SECTIONAL AREA (M2)	12.26	
CIRCUMFERENTIAL SPEED (CM/S)	125	
FILLING (%)	10.62	15.50
SPECIFIC VOLUMETRIC LOADING (TPD/ M3)	5.48	8.00
SPECIFIC THERMAL LOADING (GCAL/H/ M2)	4.29	6.26
RETENTION TIME (MINUTES)	14.56	

large. Few clusters of micro quartz grains are present.

Subhedral dolomite grains are mostly developed in association with quartz grains. Subhedral iron oxide grains with rounded grain margins are mostly fractured and shattered. Groundmass matrix is rich in carbonate minerals.

From the optical microscopy study of the thin sections of limestone samples it is observed that the major minerals of all the samples are calcite, dolomite and quartz that constitute almost 93% of the total minerals present. The average percentages of occurrence of calcite, dolomite and quartz are 56%, 15% and 20% respectively. Iron oxide and may be very fine-grained clay minerals are present as accessory minerals. Mica, orthoclase, cryptocrystalline form of quartz is observed in traces. The minimum, maximum and average grain size of all the major minerals and accessory minerals has been measured and it is observed that there exist calcite, quartz and dolomite grains are in the range of 300 to 500 $\mu$ m in some places.

## 2. Pre-blending and Homogenization

Variation in the run of mine quality (RoM) of limestone needs to be evened out and a supply of consistent uniform quality has to be maintained throughout. In order to ensure a homogenous quality of limestone, pre-blending systems have come into vogue. Stacker and Reclaimer arrangement for Pre-blending of limestone has now a days become integral part of unit operation of raw material preparation in cement manufacturing. The crushed limestone is stacked and reclaimed in a circular stockpile.

The blending efficiency is depending on stacker efficiency which in turn depends on length, width, number of layers stacked, equipment properties and raw material characteristics, and the input variability. The frequency and amplitude of the variations of material properties in the input stream has a greater impact on pre-blending. The variation in limestone during stacking is very high with min of 0.84 and max of 1.53, having Standard Deviation 0.225 in LSF. The variation in reclaimed limestone is also high.

## 3. Raw Mix Modification

The red-mud which is the process waste of Alumina Refinery is being used as corrective material. The quality of red-mud and raw mix is shown in the table 2

On interpretation of composition of raw meal, kiln feed it is observed a high variation. The quality of raw meal in terms of lime saturation factor had varied from 0.85 to 0.96; the alumina modulus also fluctuated from 0.76 to 1.01. The alumina modulus and silica modulus maintained are in the level of 0.86 and 2.16 respectively which are low.

## 4. Raw Meal Fineness Optimization

The particle size distribution is one of the important factors during the sintering process of solid particles through solid-solid or solid-liquid screening process ultimately resulting in nodulation to form clinker. Considering the quality of clinker produced, it appears that variable quantity and quality of clinker liquid phase is being formed during Clinkerization.

Burnability studies were carried out on the raw meal samples. The result of the burnability indicated that the raw meal with ~16% residue on 90 $\mu$ m size is showing good free lime pattern on relatively lower temperatures. The samples of raw meal were subjected to detailed and systematic characterization for their thermal behaviour using the state of art simultaneous DTA/TG analyser of Perkin-Elmer make. The result of thermal analysis indicated that the raw meal with ~16% residue on 90 $\mu$ m in formation of melt at lowest temperature and overall thermal behaviour is most optimum.

The samples were studied for the fusion behaviour of the various raw meal samples collected using state of art Heating Microscope. The formation of liquid content in a material primarily depends upon its chemical composition, particle size distribution, temperature and duration of exposure to high temperature, rate of heating, environment, besides others. When the samples of raw meal were tested, almost all the parameters were more or less constant except the particle size distribution which was deliberately altered to see its effect on burnability. It was found that there was a clear trend between residue on 90 $\mu$ m and extent of reduction of sample area of the test cube. It was observed that as the residue was increased, the reduction in area also decreased indicating formation of lesser liquid. Based on the heating microscope study the raw meal with ~16% residue on 90 $\mu$ m size is considered most optimum.

The microstructure study was carried out on clinker produced from raw meal of different particle size

Constituents	Lime Stone	Red Mud	Raw Mix
LSF	1.06	0.02	0.93
SM	5.04	0.23	2.16
AM	1.80	0.52	0.86
LOI (%)	36.20	14.42	34.74
SiO <sub>2</sub> (%)	14.10	13.52	14.06
Al <sub>2</sub> O <sub>3</sub> (%)	1.80	20.02	3.02
Fe <sub>2</sub> O <sub>3</sub> (%)	1.00	38.34	3.50
CaO (%)	45.0	1.54	42.10
MgO	0.80	0.64	0.79
SO <sub>2</sub> (%)	0.10	0.20	0.11
Na <sub>2</sub> O (%)	0.10	7.27	0.58
K <sub>2</sub> O (%)	0.15	0.54	0.18

distribution. The evaluation of resultant clinker from the burnability investigations by Optical Microscope revealed that considering the morphology of phases developed their quality and crystal sizes, the clinker made with raw meal with 16% residue on 90µm is most optimum.

**5. Process Optimization**

The snowmen and coating samples collected from clinker cooler, calciner and kiln burning zone were analysed for chemical composition by gravimetric method as well as by XRD to look into the presence of chemicals and phases formed. The results show high LOI of 3.1% for snowmen indicating rushing of kiln feed from 6th cyclone inlet to kiln with reduced calcinations and required phase formation.

From the XRD analysis of yellow core samples of clinker presence of free lime and high peak of C4AF

is observed which may be on account of excess of iron over alumina in raw-mix. The burning zone sample analysis give indication that presence of free lime and high peak of C4AF which may be on account of excess of iron over alumina in raw-mix.

From the XRD analysis of burning zone sample it is observed that unstable belite is present and surprisingly CaCO<sub>3</sub> is observed. This corroborates the thinking of rushing of kiln feed from 6th cyclone inlet to kiln. The XRD analysis of calcination zone coating samples indicates the presence of Mayenite Thenardite (Na<sub>2</sub>SO<sub>4</sub>) and C12A7 might be due to leaching out of alumina from refractory.

**MODIFICATIONS AND CORRECTIONS**

The input variability and the frequency & amplitude of the variations of material properties in the input stream have a greater impact on pre-blending efficiency. The

deterioration of quality (CaO content) is due to the influence of clay/Gravel present. The screening system is implemented to remove the clay/Gravel from the limestone. Two points loading is practiced to bring down the amplitude of the variations of material properties in the input stream. The limestone piles are made in segmented linear type pile in chevron mode stacking. The number of layers is increased by optimizing the stacker speed. The filling cycle and extraction cycle pattern of raw-meal silo changed from consecutive to alternate gates with cycle time reduction from 180 sec to 160 sec. The raw meal fineness is maintained at 16% on 90µm which is most optimum particle size distribution for improved burnability and productivity. The alumina modulus increased from 0.86 to 1.05. The size of MFR in clinker cooler optimized to increase the cooling efficiency.

### **CONCLUSION**

The systematic study of raw materials and with minor modification in the physical and chemical properties in the raw meal will lead to improvement in the kiln productivity. In the case of ABC Cement Ltd., the kiln productivity has been consistently achieved 140% over the designed capacity (that is from 4500TPD to 6500TPD) which has resulted to capacity addition of 0.6 million Ton of clinker without any capital investment.

### **END NOTES**

In the product like cement which is primarily a low value product, with high incidence of taxes and duties, high energy costs, the avenues available to a plant for reducing its costs are limited. In the present environment due to energy crisis and steep increase in the cost of energy and other input materials, it has become imperative to give serious thought on how to make operations and equipment efficient towards use of energy and adoption of latest technology equipment to retain the requisite competitive edge in the market.

Based on the several studies in the field of operational audit, it has been observed and proven that production level can be improved and energy consumption can be reduced by:

1. Doing continuous process diagnostics investigations / monitoring
2. Process optimisation
3. Maintaining the preheater and pre-calciner strings, dedusting system, ducting

4. Providing quality utility services in terms of compressed air quality, water quality, etc.

A plant audit is the basis for optimizing plant operations and often has the lowest/benefit ratio of investment. The operations audit can be a beneficial first step in aiding the industrial and process engineer in assessing the appropriate focus for later problem-solving efforts and can be used in a variety of circumstances in most production and operations environment.

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He is passionate to first optimize the Plant without any CAPEX or with little investments to achieve Productivity Enhancement with implementation of innovative ideas and small up-gradations.

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