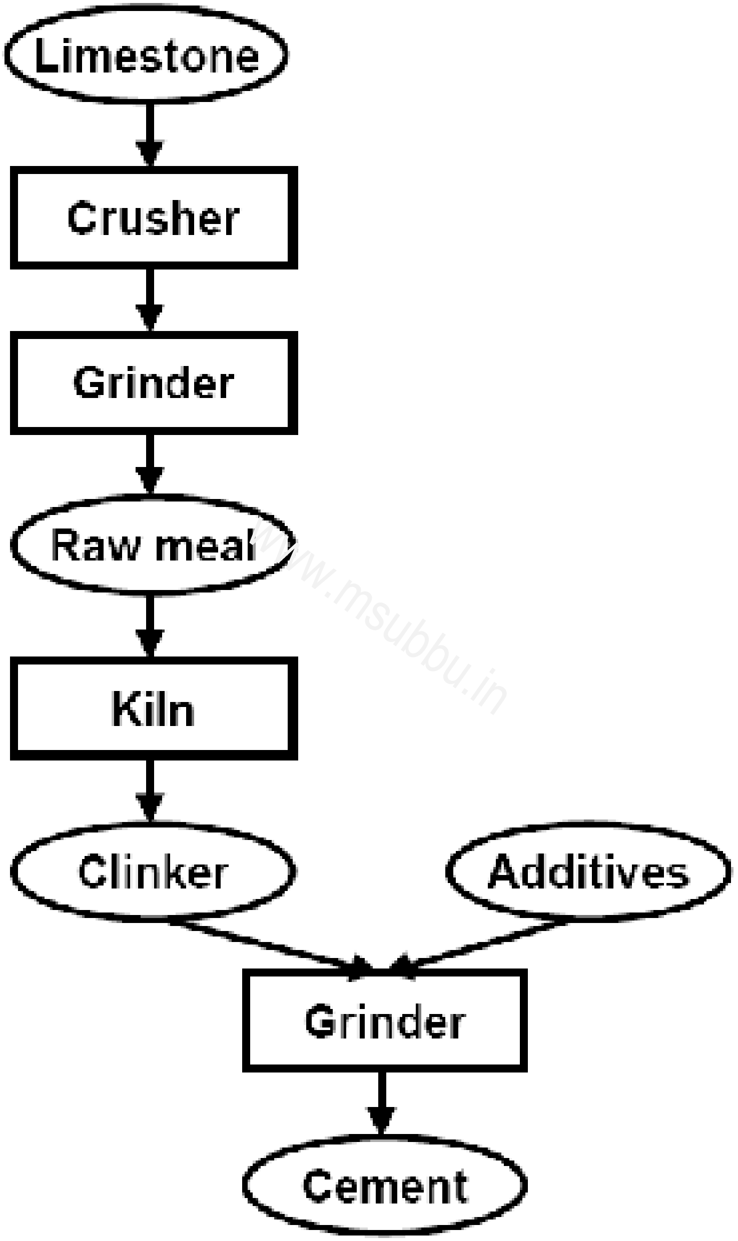
Energy Saving Measures in Cement Industry

Dr. M. Subramanian

Associate Professor
Department of Chemical Engineering
Sri Sivasubramaniya Nadar College of Engineering
Kalavakkam – 603 110, Kanchipuram (Dist)
Tamil Nadu, India
msubbu.in[AT]gmail.com

Cement Industries - India

- Per capita consumption: 100 kg / year
- Growth rate: 8%
- Per capita consumption of developed countries: 255 kg
- Energy cost: 45% of manufacturing cost
- 124 major cement plants (as on 2002); installed capacity: 135 million tons / year


Limestone
Crusher
Grinder
Raw meal
Kiln
Clinker
Additives
Grinder
Cement

Cement Manufacturing Process

- Cement acts as a bonding agent, holding particles of aggregate together to form concrete.
- Cement production is highly energy intensive and involves the chemical combination of calcium carbonate (limestone), silica, alumina, iron ore, and small amounts of other materials.
- Cement is produced by burning limestone to make **clinker**, and the clinker is blended with additives and then finely ground to produce different cement types.
- Desired physical and chemical properties of cement can be obtained by changing the percentages of the basic chemical components (CaO, Al2O3, Fe2O3, MgO, SO3, etc.).

Cement Manufacturing Process

- **Clinker** is made by one of two production processes: wet or dry. In the wet process, the crushed and proportioned materials are ground with water, mixed, and fed into the kiln in the form of a slurry. In the dry process, the raw materials are ground, mixed, and fed into the kiln in their dry state.

- The dry process is the more modern and energy-efficient configuration.

- In modern kilns, the raw material is preheated (in four to five stages) using the waste heat of the kiln, or it is pre-calcined.

Cement Manufacturing Technologies

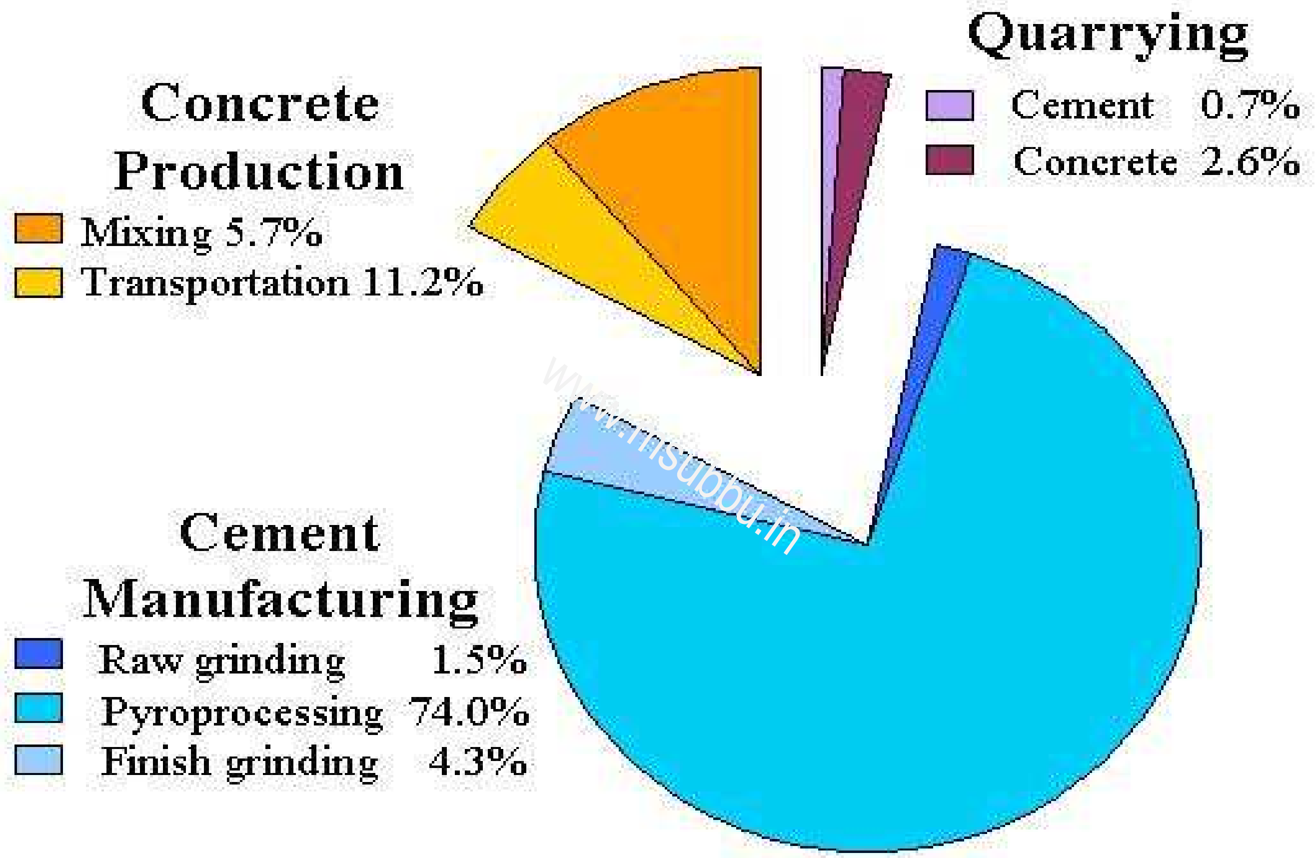
- In India, three types of processes are being used for cement manufacture and are given below:
  - Wet process < 5% of the production (older plants)
  - Dry Suspension (SP) process < 8% of the production
  - Dry Precalciner (PC) process > 85% of the production

Energy Consumption in Various Stages

- **Raw materials preparation** accounts for a small fraction of overall primary energy consumption (less than 5%) although it represents a large part of the electricity consumption.

- **Clinker production** is the most energy-intensive step, accounting for about 80% of the energy used in cement production.

Diagram A – Energy Use Distribution for Quarrying, Cement Manufacturing and Concrete Production



See : Appendix A Table A.10

Energy Usage Pattern

- **Primary energy consumption** in a typical dry process Portland Cement Plant as found in industrialized countries consists of up to 75% of fossil fuel consumption and up to 25% of electricity consumption.

- **Within the fuel category** pyroprocessing requires the most energy, consuming 99% of the fuel energy while electricity is mainly used to operate both raw material (33%) and clinker (38%) crushing and grinding equipment. In addition, electricity is needed for pyroprocessing (22%) making it by far the most energy intensive step of the production process.

Energy Saving Options in Brief

- Upgrading existing equipment
  - shifting to more energy-efficient processes (e.g. from wet to dry process, from dry process to preheater)
  - installing improved heat recovery systems from clinker coolers
  - installing new design high-efficiency crushing, grinding, and milling equipment

- Adopting new pyro-processing technologies – fluidized bed kiln, cogeneration

- Utilizing biomass fuels, and waste fuels

- Changing cement product formulations, applying a lower clinker to final cement mixture ratio (i.e., increasing the ratio of cement additives that do not require pyro-processing)

Typical Energy Balances for Pyro-processing

Table 9 Thermal Energy Balances to Produce Clinker in Process Kilns

	Wet Kiln		Dry Kiln		Preheater Kiln	
Energy Use Area	Btu/tonne	Percent	Btu/tonne	Percent	Btu/tonne	Percent
Theoretical Requirement	1,690,000	30.5	1,730,000	36.6	1,670,000	49.6
Exit Gas Losses	713,000	12.9	1,310,000	27.7	471,000	13.8
Evaporation of Moisture	2,120,000	38.3	285,000	6.0	223,000	6.5
Dust in Exit Gas	10,700	0.2	12,300	0.3	1,220	0
Clinker Discharge	53,700	1.0	58,000	1.2	62,400	1.8
Clinker Stack	180,000	3.3	560,000	11.8	582,000	18.4
Kiln Shell	642,000	11.6	575,000	12.1	166,000	4.9
Calcination of Waste Dust	38,600	0.7	17,500	0.4	5,870	0
Unaccounted Losses	84,300	1.5	182,000	3.8	164,000	4.8
TOTAL	5,536,000	100	4,734,000	100	3,424,000	100

Source: *The Rotary Cement Kiln*, Kurt E. Perry, Chemical Publishing Co., Inc., New York, page 107-111

Energy saving possibilities in pyro-processing

- The large energy efficiency difference between cement processes, from 5,536,000 Btu/tonne of clinker for wet process to 3,424,000 Btu/tonne of clinker for dry process with preheater, shows the significant gains that can be made by upgrading to the more efficient process.

- The individual energy use areas (e.g., clinker discharge, kiln shell, etc) in Table 9 show the area and the magnitude of the opportunities available from managing energy losses by improving specific equipment or practices

Kiln Operations

- Pyroprocessing in giant rotating furnaces or kilns represent the major technical process common to all cement plants. It is also the most technically complex and energy-intensive operation from quarrying to concrete placement.
- Rotary cement kilns are cylindrical, refractory-lined steel furnaces that range from 200 to more than 1,000 feet long and from 10 to over 25 feet in diameter.
- Cement kilns are the world's largest piece of moving industrial process equipment and one of the hottest.

Improving Efficiency by Energy Auditing in Pyro-processing

- Lower kiln exit gas losses
- Lower clinker discharge temperature (retaining more heat within the pyroprocessing system)
- Lower kiln radiation losses by using the correct mix and more energy efficient refractories to control kiln temperature zones
- Lower cold air leakage

Product Formulation Changes to increase Energy Efficiency

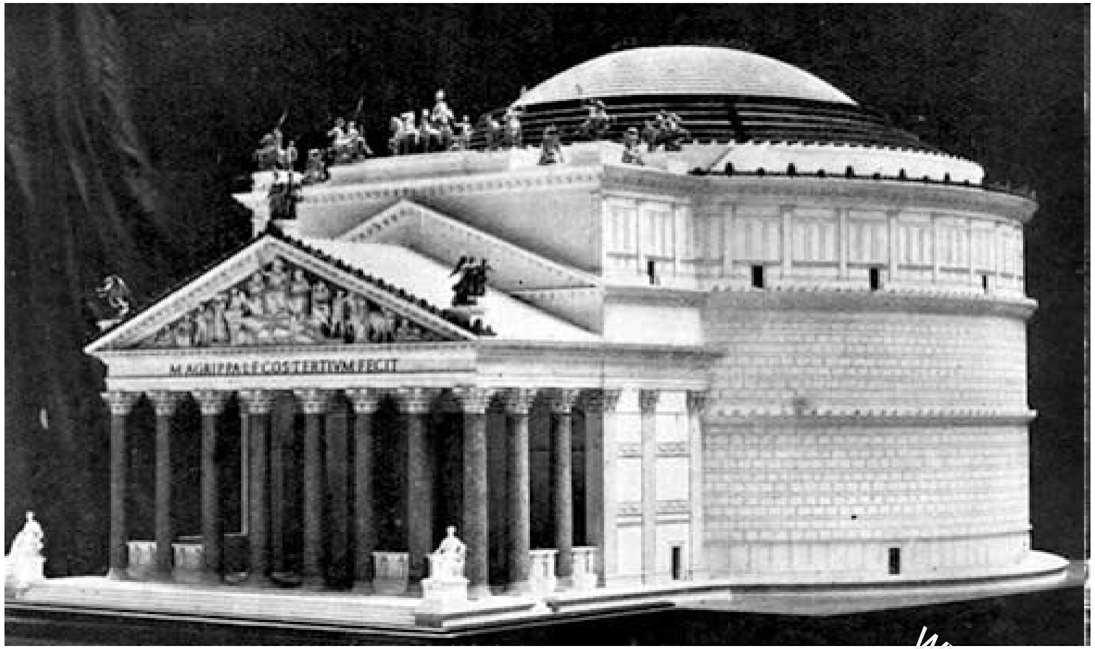
- Energy efficiency improvements and emission reductions can also result from changes in the Product Formulation of cement.

- These modifications include the addition of limestone and other cement-like materials (e.g., fly ash, furnace slag, or other pozzolanic materials) that do not require the large energy inputs and emissions associated with pyro-processing

- This change in product formulation results in roughly a 5% decrease in energy use and a 2.6% reduction in CO_2 emissions.

Pozzolan

- Materials that can be added to cement to extend its volume without a significant loss of properties are known as “pozzolans.”
- They are named after the ash deposits adjacent to the Pozzol volcano that the Romans used as cement.
- The Pantheon in Rome is a testament to the high strength and durability of pozzolan cement. Its hemispherical dome, 141 feet (43 meters) in diameter, is made completely from pozzollan cement and does not contain any reinforcing bars. It has been in use since 135 A.D. (for comparison the U.S. Capital dome is 96 feet in diameter)



Almost two thousand years after it was built, the **Pantheon's dome (Rome, Italy)** is still the world's largest unreinforced concrete dome.

Pozzolan (contd.)

- Pozzolanic materials can combine with uncarbonated lime (calcium hydroxide) to form stable compounds, thus reducing the risk of early leaching or frost damage and increasing the potential durability of the mortar.

- Pozzolan materials, in general, do not require pyroprocessing and, hence, can save very significant quantities of energy and lower emissions when supplementing regular cement. Concrete research is now calling for increased usage and high-volume usage of pozzolans, especially fly ash

- Coal-fired power fly ash is sometimes used as a source of silica in cement manufacturing, but more commonly is used in concrete production as a substitute for a portion of the cement. This is beneficial in two ways: it reduces solid waste and overall energy use since it does not require pyroprocessing. Fly ash can readily be substituted for 15% to 35% of the cement in concrete mixes and in some applications fly ash content can be up to 70%.

Pozzolan (contd.)

- Fly ash and slags react with any free lime left after the hydration to form calcium silicate hydrate, which is similar to the tricalcium and dicalcium silicates formed in cement curing. This process increases strength, improves sulfate resistance, decreases permeability, reduces the water ratio required, and improves the pumpability and workability of the concrete.