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December 1986
ENGLISH

PRODUCTIVITY IMPROVEMENT
THROUGH
CEMENT RAW MATERIALS TECHNOLOGY
DP/IND/84/020/11-03/31.4.B
INDIA

Technical report: Evaluation of mix design, clinker properties and flammability of coal in selected Indian cement plants

Prepared for the Government of India
by the United Nations Industrial Development Oganization
acting as executing agency for the United Nations Development Programme

Based on the work of George R. Gouda,
expert in cement technology

United Nations Industrial Development Organization
Vienna

This report has not been cleared with the United Nations Industrial Development Organization which does not, therefore, necessarily share the views presented.

I EXPLANATORY NOTES

Usual technical abbreviations

1 Cement science

$S = SiO_2$

$A = Al_2O_3$

$F = Fe_2O_3$

$C = CaO$

L.O.I. = Loss on ignition

$$S.M. = \frac{SiO_2}{Al_2O_3 + Fe_2O_3}$$

$$A.M. = \frac{Al_2O_3}{Fe_2O_3}$$

$$H.M. = \frac{CaC}{SiO_2 + Al_2O_3 + Fe_2O_3}$$

$$L.S.F. = \frac{CaO}{2.8\ SiO_2 + 1.18\ Al_2O_3 + 0.65\ Fe_2O_3}$$

$$C/S = \frac{CaO}{SiC_2}$$

$C_3S = 4.071\ C\ (7.6\ S + 6.72\ A + 1.43\ F)$

$C_2S = 2.867\ S - 0.7544\ C_3S$

$C_3A = 2.65\ A - 1.692\ F$

$C_4AF = 3.043\ F$

L.P. = liquid phase, calculated at 1,400°C

$= 2.95\ A + 2.2\ F + MgO + Na_2O + K_2O$

I.R. = Insoluble residue

F.L. = Free lime

C.L.W. = Clinker liter weight

SP = Suspension preheater

PC = Precalciner system

ESP = Electrostatic precipitator

2 Coal science:

H.H.V. = High heating value (kcal/kg)

L.H.V. = Low heating value (kcal/kg)

U.H.V. = Useful heating value (kcal/kg)

3 Production abbreviations:

mtph = metric ton per hour

mptd = metric ton per day

mtpy = metric ton per year

Unfamiliar acronyms, etc.

ERI : Cement Research Institute

NCB : National Council for Cement and Building Materials

ACC : Associated Cement Corporation

CCI : Cement Corporation of India

F.L.S.: F.L. Smidth, Denmark

I.H.I.: Ishikawajima - Harima Heavy Industries Co., Ltd., Japan

OPC : Ordinary Portland Cement

PPC : Pozzolanic Portland Cement

LFRM : Loss free raw mix

BWI : Bond Work Index

(Note: All the chemical analysis represents the percent by weight.)

ACKNOWLEDGMENTS

The author would like to thank Dr. H. C. Visvesvaraya, the Chairman and Director General of the National Council for Cement and Building Materials; Mr. D. B. Irani, the Director of the National Council; and all the staff of NCB who are associated with this project for their assistance, and arranging the trips to all the cement plants, which made this mission successful. Also thanks to the personnel of the cement plants visited for their cooperation and the successful discussions.

II. ABSTRACT

Title : Productivity Improvement through Cement Raw Materials Technology

Number : DP/IND/84/020/11-03/31.4.B

Objective : To improve the industry's productivity and the technological level of various units of the cement industry in India by strengthening the national center, the National Council for Cement and Building Materials.

Duration : Two Months

Main conclusions and recommendations

1 Eight cement plants were visited to evaluate their raw materials deposits, raw mix designs, flame shape and clinker quality. These visits were arranged by the National Council for Cement and Building Materials. Each plant has different problems associated with the raw materials.

2 Limestone of variable qualities is the main component used in the cement industry in India. Most of the cement plants are working without having a complete prospection of the raw materials. In this respect, the National Council of Cement and Building Materials can expand its activity to those plants to perform complete study and evaluation of the deposits.

3 Some of the cement plants produce clinker with high C_2S and low C_3S contents. This is due to poor quarry operations which are operated by the technique--"blast it all .... take it all," while few plants use selective quarrying. The National Council has the capability of presenting the recommendations for such raw materials deposit, for selective quarry operation either manually or using a computer program and to perform burnability tests.

4 Clinker quality is variable with high free lime and high expansion in the cement for some plants, due to poor quality control, inefficient blending system and different operational and productional problems. Efficient preblending and blending systems for most of the Indian cement plants will provide homogenous feed to the kiln resulting in efficient operation and improvement in the production. Using the dust collected as a kiln feed without homogenization results in an inferior clinker quality. The National Council for Cement and Building Materials can strengthen and assist these plants in setting up their control parameters

with the objective of production improvement, qualitatively and quantitatively.

5 All of the cement plants use coal with high ash content, low volatile matter and heterogeneous in quality. The flame shape is impingement in most of the plants. In this respect, the use of coal with less than 30% ash content and with a flame temperature up to 1,500°C is highly recommended. Blending the coal and maintaining a supply of 10 - 15 days should be assured for each plant. The National Council has designed a burner nozzle that works satisfactorily. This can be extended to the other cement plants.

6 As it is the intention of the government targets to double the capacity of the cement plants by AD 2000, it is recommended that the National Council should set up the requirements and conditions of the erection of the new cement plants; review the raw materials studies, quarry operation, raw mix designs, and general layout of the plant, etc. This will assure that the new cement plants will be erected after thorough studies using the most recent technology. The National Council should be reimbursed for this study.

7 Most of the cement plants are not aware of quality control by use of microscope techniques. In this respect, the National Council can offer extensive courses to train the plant personnel on this technique, and establish a data bank at the headquarters of the Council for the clinker microscopy of all the Indian cement plants with an objective of different approaches for productivity enhancement. Organizing a conference on clinker microscopy by the National Council can be forseen.

8 The National Council should assign and recruit (if it is required) at least eight highly technical personnel to specialize in cement raw materials technology--starting from deposits to clinker quality; including flammability, operation, production bottlenecks, etc. This group should be selected on the basis of staying at the National Council (not changing their job) and training at different international selected cement plants on know-how.

9 The National Council should develop a simulator for the different processes of cement production and arrange for staff from the council and from the cement industry to visit several plants and engineering companies abroad. This will help in the transfer of technology.

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IV INTRODUCTION

Presently, the cement industry in India comprises 94 cement plants--including public and private sector, and mini cement plants. The annual installed capacity is about 36.5 million mtpy. The per capita consumption of cement in India is only 43 kg as compared to 693 kg in Italy, 591 kg in Japan and 442 kg in South Korea. It is planned to reach a capacity of about 100 million tons by the turn of the century.

Limestone and fuel are the basic raw materials for cement production. Unlike in many other countries, the cement industry in India, for the most part, has to face and to utilize a relatively lower grade of limestone since the best quality of limestone is used by the chemical industries, and large reserves of high quality limestones are reserved exclusively for the steel industry. The limestone used for the cement industry is of very poor quality with variable composition and free silica, and in some places with high percent of calcite crystals. Coal supply for the cement industries has a very high ash content that varies from 30 - 50%.

The National Council for Cement and Building Materials, (attached to the Ministry of Industry, Government of India), is the National Centre devoted to research technology development and transfer, education, and industrial services. The National Council has made numerous contributions towards serving the cement and allied industries. Some of its contributions include training courses, design, development and installation of totally indigenous coal-fired precalciner, development of vertical shaft kiln for mini cement plants, norms for prospection of cement raw materials, utilization of industrial wastes and low grade raw materials for cement manufacture, technical publications, etc.

In the past, the cement industry has managed to utilize the coal supplied to the plants and accommodate the coal ash and maintain quality and cement specifications for the grade required. Recently--since the quality of limestone is deteriorated due to poor raw materials prospections and the high ash content--the quality of the clinker is affected as well as the production of the plants is decreased. The National Council is tackling this problem by a comprehensive program funded by UNDP with the aim of "Productivity Enhancement and Modernization Program of NCB." This program was developed and established in 1976 with the Cement Research Institute (CRI) to provide an effective interface between the National Council and the Indian cement plants by assisting the plants in enhancement of productivity, troubleshooting, and adopting the latest techniques of R&D and know-how brought from outside. The program involves more than 30 UNDP experts comprised of short- and long-term consultants--on split mission basis--in various areas, over some three years.

The objectives of this program is to strengthen the existing capabilities of NCB and its technical staff in productivity enhancement of the cement industry to:

- effectively diagnose the technical problems and the constraints in the cement industry
- formulate programs and methodologies for solving technological problems with the aim of improving production of cement plants and implementing the solutions with the incorporation of the industry. It is expected the following will be achieved:
  - increase the present utilization capacity of the cement plants
  - introduce energy conservations to reduce the power and energy consumptions
  - reduce dust emissions
  - convert as many as possible of wet cement plants to dry process
  - decrease kiln downtime

The output of this program is

- availability of trained manpower--both at NCB and in the cement industry
- improved expertise in effectively diagnosing production problems, formulating and implementing various programs of troubleshooting, productivity optimization and enhancement, expansion and modernization of cement plants.

This assignment is concerned with productivity improvement through cement raw materials technology. The area of approach embodies correlating the effect of raw material composition on:

- raw mix design
- quality of clinker
- operational efficiency
- coating and jamming problems in kiln and cyclones, respectively
- formulating remedial measures.

In addition, a reduction in heat, power consumption and dust emission is also envisaged together with establishment of a data base at NCB for monitoring the various productivity indicators.

The objective of this mission was attained by visiting eight different cement plants and collecting the information concerned with the chemistry and properties of raw materials, raw mix, dust, coal and coal ash, clinker quality, clinker absorption of the ash, burning process, flame shape, etc. Each visit was accompanied by two experts from the NCB to strengthen their expertise in raw materials technology. The technological problems and productivity constraints were effectively diagnosed in the presence of NCB staff and the plant personnel. A questionnaire was distributed to each plant to fill in the information related to the raw materials, raw mix, and plant production. A report was written for each visit and attached to the information collected from the plant. Recommendations were given to improve the plant efficiency and clinker quality with regard to the raw mix design, raw material grinding, burning process, ash quality, flame shape, etc. The following is a list of the plants visited:

1 Shree Digvijay Cement, Sikka (Gujarat)
2 Saurashtra Cement and Chemical Industries, Ranavav (Gujarat)
3 Cement Corporation of India Ltd., Nayagaon (Mandasaur)
4 Lakshmi Cement Ltd., Jayhaypuram, Banas (Rajasthan)
5 Shree Cement Ltd., Beawar (Rajasthan)
6 Panyam Cement and Mineral Industries, Cement Nagar (Has Kurnool)
7 Durga Cement Works, the Andhra Cement Company Ltd., Durgapuram (Dachepalli)
8 Madras Cement Limited, Ramaswamy (Raja Nagar).

V RECOMMENDATIONS

Cement making is a chemical process where expensive and complicated machinery is required to prepare the raw mix for the necessary reactions and where no single step in the operation can be considered secondary to any other step if quality is to be achieved. Top-grade cements require top-grade control of the raw materials, coal and all the different processes. The following recommendations are the result of the first mission and it is concerned with the raw materials, raw mix, coal, kiln operation and flammability, fuel and power consumptions, clinker quality, dust, pyroprocess, etc.

1 The kiln feed must be uniform--chemically and physically. Adequate and economic mix design should feed the kiln. Composition control begins at the quarry, and to achieve this, the following is required from the cement plants:

- a complete prospection of the raw materials deposits
- adopt the computer program for quarry operation and select the required raw materials. Impurities to be removed
- a preblending system with high preblending factor, to be covered in the case where the cement plant is located in a high rain area
- an efficient raw mill grinding with optimum particle size of product and minimum moisture content
- a blending system for blending the raw meal. The kiln feed should be adjusted so that the clinker falls within the following parameters, after considering the coal-ash absorption:

S.M.	: 2.2 - 2.5	C_3S	: $\simeq$ 52
A.M.	: 1.2 - 1.5	C_2S	: $\simeq$ 22
H.M.	: 2.1 (±0.05)	C_3A	: 8
L.S.F.:	: 92 - 95%	C_4AF	: 12
C/S	: 3.15 (±0.1)	C_3S/C_2S	: 2 (minimum)
L.P.	: $\simeq$28%		

2 Use of high amounts of sweetener is recommended to obtain high H.M., L.S.F. and C_3S. Presence of free SiO_2, calcite crystals and igneous rocks in the raw mix render it to be burned. This can be compensated by adding iron ore, but not at the expense of the other components and the liquid phase. In the case of any variation in the raw materials blasted, perform a burnability test to determine the new parameters of the mix that produces high quality of the clinker with optimum kiln operation.

3 The coal used to sinter the raw materials in the rotary kiln should have:

- high quality and ash content less than 30%

- high heating value in order that the burning temperature ($\simeq$ 1,500°C) can be obtained. It may be necessary to blend local coal with another imported coal and/or use low ash lignite. Coal should be dried before burning it in the kiln.
- adequate coal fineness to the kiln and the precalciner. Experiments should be performed to determine the optimum size
- minimum amount of primary air and avoid flame impingement directly into the clinker load in the burning zone are of the utmost importance to avoid undue coal ash contamination.
- a proper burner pipe which creates turbulence in the burner tip and swirling motion to the coal stream.
- a short burning zone as close to the discharge point of the kiln as possible, and within practical limits will minimize the coal ash contamination in this zone. The burner pipe can be parallel to the kiln axis, horizontal or pointed down to achieve flame that releases its heat in the most desirable location
- a supply of 10 - 15 days should be available and the coal should be blended before grinding to supply uniform ash content and temperature
- the coal should be characterized before burning it and the kiln feed should be adjusted accordingly.

4 Any increase or decrease in the amount of dust returned to the kiln upsets the kiln stability and the production rate of the kiln. Dust, when it is used, should be blended efficiently and with a continuous rate with the mill product in the blended silos. However, using the collected dust should be engineered carefully, where the kiln feed, dust system and their instrumentations should be capable of preventing wide variations. In this respect, it is recommended that the National Council should carry out studies on the dust collected from different points and their effect on the kiln performance and clinker quality.

5 An automated process control system should be considered, especially the rotary kiln, where small deviations can be recognized and small adjustments can be made. By this technique, steady-state conditions are nearly achieved. A successful automated system improves the kiln operation, reduces fuel consumption, increases production rate, increases refractory life, and reduces the frequency of shutdowns.

6 Clinker quality is to be determined by using the microscope techniques, where the size, amount, dispersion and morphology of the clinker phases formed during the clinkering process can be obtained. The Bogue

computation of clinker compounds does not always indicate the actual abundance of phase formed, and considerable deviation from the computed composition may occur. Microscopic techniques permit the evaluation of clinker deviation in such a manner that appropriate steps to ensure quality cement can be taken.

7 Sampling system should be precise and should not depend on periodic grab samples. Automatic or continuous sampling is recommended to achieve a representative sample.

8 Avoid all the leakage points to the pyroprocessing system and install efficient kiln sealings. This will help in reducing fuel consumption and stabilizing the kiln operation with high clinker quality (if uniform feed is used) and low energy consumption.

9 For the plants that have several bottlenecks, it is recommended to study rehabilitation of the different equipment and perform complete heat and material balances. Install new equipment or repair the equipment which is out of order. Increase the capacity of the existing equipment if the present capacity is not balanced with the kiln production.

10 For the plants where the energy consumption/ton of cement is high (more than 105 kwh/t), it is recommended to have an energy audit through all the plants with the objective of reducing the energy consumption.

11 To increase the efficiency of quality control starting from the crusher to the packing house, it is recommended to the cement plants to acquire more technical magazines, to participate in local and international seminars, and to modernize the lab equipment. It is recommended to use X-ray fluorescence to control the CaO content of kiln feed rather than using the acid-alkali method.

12 To acquire a simulator for the pyroprocessing process at NCB and train the burners of the cement plants.

13 The minor constituents should be determined for the following materials as follows:

		Cl	SO_3	Na_2O	K_2O	C
Raw materials	:	X	X	X	X	X
Kiln feed	:	X	X	X	X	X
Dust	:	X	X	X	X	X
Coal	:	X	X			X
Coal ash	:		X	X	X	

and keep a record of these constituents.

14 Power should be supplied to the plant continuously and without interruption.

The National Council for Cement and Building Materials should train the staff and update their technical ability regularly to undertake the full responsibility to accomplish the above-mentioned recommendations. The National Council has the capability and the ability--manpower, equipment, facilities--to help the cement plants in solving their production problems.

VI ACTIVITIES AND OUTPUT

A. Job description and objectives of the activity

The main duties of this first mission as it is explained in the job description cover the entire spectrum of activities relating to raw materials with emphasis on "Raw mix design and flammability studies." The objective of the first mission is to strengthen the existing capabilities of the National Council for Cement and Building Materials (NCB) in productivity improvement through raw materials technology. The area of approach embodies correlating the effect of raw material composition on:

- quality of clinker
- operational efficiency
- coating and jamming problems--kilns and cyclones
- formulating remedial measures

By analysis of these problems and the interaction with NCB and plant personnel in diagnosis of the technical problems and production constraints, a program and methods for solving these problems with the aim of improving the production will be possible.

In the energy field, activities are to include:

- reduction in heat, power consumption and dust emission
- establishment of a data base at NCB for monitoring the various productivity indicators.

The job description and the work plan put out by NCB follow this page.

B. Technical activities

Eight different Indian cement plants were visited. Each plant was visited for a period of approximately two complete days. A questionnaire regarding raw materials, raw mix, coal, coal ash, clinker, process, operational parameters, fuel and energy consumption and production problems was prepared and given to each plant visited. All the departments were visited, from raw materials deposits to clinker production. Intensive discussions with the management and the production personnel took place. In some plants, brief presentations on raw mix parameters, quality control, burnability test, clinker quality by microscope, etc., were given in a question and answer and slide presentation method. A report for each plant visited was prepared including observations, production problems, recommendations to improve quality--quantitative and qualitative. The information collected is also attached to each report. These reports are attached herewith in Annex 2 - 9 and are as follows:

Annex 2: Report on visiting Shree Digvijay Cement

Annex 3: Report on visiting Saurashtra Cement

UNITED NATIONS

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

UNIDO 21 May 1985

PROJECT IN THE REPUBLIC OF INDIA

JOB DESCRIPTION

DP/IND/84/020/11-03/31.4.B

Post title	Expert in Productivity Improvement through Raw Materials Technology
Duration	Split mission - two months in the first mission and the possibility of a further four months in subsequent missions
Date required	1 November 1985
Duty station	New Delhi, with frequent visits to cement plants and the possiblity of travel to other NCBM units within the country as required.
Purpose of project	To improve the industry's productivity and the technological level of the various units of the cement industry in India by strengthening the national centre, the National Council for Cement and Building Materials (NCBM).
Duties	The expert will be attached to the NCBM and will be part of an international team led by the Project Director. The expert will work under the supervision of the Council's Chairman and Director General.

Whilst the expert's sphere of work will cover the entire spectrum of activities relating to raw materials technology, special emphasis will be placed upon:

First mission: Raw mix design and flammability studies in selected Indian cement plants.

Subsequent missions: Suitable matching characteristics of various raw materials and fuels, which will produce good quality clinker out of lower grade limestone and coal in selected cement plants, research into the use of mineralisers in the manufacture of cement.

..../..

The expert will specifcally be expected to assist the NCBM in strengthening its existing capabilities by:

1. Effectively diagnosing technological problems and productivity constraints.

2. Formulating programmes and methodologies for solving technical problems and improving productivity.

3. Implementing the above-mentioned programmes and methodologies to enable the NCBM, in co-operation with the industry, to achieve a higher utilization of capacity, a reduction in the consumption of power, a reduction in dust emission, a reduction in kiln down time and to establish a central data base at the NCBM for monitoring the various productivity indicators.

The expert will also be expected to prepare a final report, setting out the findings of the mission and recommendations to the Government on further action which might be taken.

Qualifications

Chemist/technologist or engineer with extensive experience, including adequate experience at a senior level, in raw material technology in the cement industry. The expert should also have a sound background in productivity management in connection with the above and be familiar with the methodologies of studies on productivity enhancement.

Language

English

Background information

The cement industry in India comprises 94 cement plants with a total annual installed capacity of 36.5 million tonnes. The available raw materials, especially the limestone, are generally of a very poor quality with a high silica and magnesia content. The coal also has a very high ash content, in the order of 40% or even higher, which means that the various raw material components need to be matched very carefully.

The National Council for Cement and Building Materials, (which is attached to the Ministry of Industry), is the national centre devoted to research technology development and transfer, education and industrial services. It provides the necessary technological services to the cement industry at the national level. The institute has an on-going programme of productivity enhancement and modernization and a number of cement plants have already derived benefits from the same.

CANDIDATES REQUESTED BY 16 JULY 1985

UNDP PROJECT IND/84/020 - STRENGTHENING NCB CAPABILITIES IN PRODUCTIVITY ENHANCEMENT OF CEMENT INDUSTRY (PEP)

Tentative work plan for UNDP Expert Dr G R Gouda for Post 11.03 - Expert in Productivity Improvement through Raw Materials Technology

FIRST MISSION OF TWO MONTHS - BEGINNING 02 OCTOBER 1986

The objective of first mission is to strengthen the existing capabilities of NCB in productivity improvement through raw materials technology. The area of approach embodies correlating effect of raw material composition on (i) quality of clinker, (ii) operational efficiency, (iii) coating and jamming problems in kiln and cyclones (in dry process kilns) etc and formulating remedial measures. It is expected that through effective interactions with NCB and plant personnel, the expert shall assist NCB in strengthening the expertise in raw materials technology by effectively diagnosing technological problems and productivity constraints, formulating programmes and methodologies for solving the technical problems and improving productivity. In addition, a reduction in heat, power consumption and dust emission is also envisaged together with establishment of a data base at NCB for monitoring the various productivity indicators.

PROGRAMME SCHEDULE (TENTATIVE)

Activity	Date
UNDP Mission Formalities	03 Oct 1986
Briefing by the Project Director and Chairman & Director General - NCB	06 Oct 1986
Discussion with Director - NCB	06 Oct 1986
Discussion with NCB Officials on various aspects of raw materials technology	06 to 07 Oct 1986
Visit to Digvijay Cement, Jamnagar	08 Oct 1986
Interaction with plant personnel on the problems relating to raw materials and their burnability	08 to 09 Oct 1986
Visit to Saurashtra Cements & Chemical Industries, Ranavav	10 to 11 Oct 1986
Interaction with plant personnel on the problems relating to raw materials and their burnability	
Departure for Bombay	12 Oct 1986
A talk in Bombay (Topic to be announced)	13 Oct 1986
Back to Delhi	13 Oct 1986
Interaction with NCB Counterparts and preparation of visit report by the team	14 to 17 Oct 1986
Visit to CCI Nayagaon	Dep: 19 Oct 1986
Interaction with plant personnel on the problems relating to raw materials and their burnability	20 to 21 Oct 1986
Departure for Lakshmi Cement and Shree Cement	22 Oct 1986
Visit to Lakshmi Cement & Shree Cement (Beawar) Interaction with Plant personnel on the problems relating to raw materials and their burnability etc	22 to 24 Oct 1986

Back to NCB, Delhi	25 Oct 1986
Interaction with NCB Counterparts regarding visits done so far and expert comments on various aspects of raw material problems of plants in the formal and informal talks and finalization of reports on each Plant	27 to 31 Oct 1986
A talk at CCE-NCB Ballabgarh/Delhi (Topic to be announced)	29 Oct 1986
Visit to Andhra Cement	Dep: 04 Nov 1986
Interaction with the plant personnel regarding the problem being faced by them in the raw materials field	04 to 05 Nov 1986
A talk in Hyderabad (Topic to be announced)	06 Nov 1986
Departure for Panyam Cements	06 Nov 1986
Interaction with the Plant personnel regarding the problem being faced by them in the raw materials field	07 to 08 Nov 1986
Departure for Madras Cement	09 Nov 1986
Interaction with the plant personnel regarding the problem being faced by them in the raw materials field	10 to 11 Nov 1986
Back to Delhi	12 Nov 1986
Interaction with NCB Counterparts on the outcome of mission and finalisation of mission report by Expert	13 to 25 Nov 1986
Finalization of Mission	26 Nov 1986
Debriefing with Project Director	26 Nov 1986

Annex 4: Report on visiting Cement Corporation of India

Annex 5: Report on visiting Lakshmi Cement Ltd.

Annex 6: Report on visiting Shree Cement, Beawar

Annex 7: Report on visiting Panyam Cement

Annex 8: Report on visiting Durga Cement Works

Annex 9: Report on visiting Madras Cement Ltd.

All these eight cement plants are working by dry process using the suspension preheater system with or without a precalciner.

In this respect, and to accomplish the maximum advantage of the visit to each plant and to enhance its production, it is advisable to ask for the guidance of the National Council for Cement and Building Materials. Continuous interaction between the cement plants and the National Council will benefit not only the cement plants on short and long terms, but also will benefit the National interest.

C. Observations and findings

The following are the observations noted during the visits to the eight cement plants. They are numbered in descending order of the process and not in priority. In general, each point is important for smooth plant operation and to enhance the productivity.

1 Raw materials deposits: The deposits vary from high to low quality of limestone, which are mixed together in an irregular pattern and with variable proportions. Contaminations such as clays, quartz and "calcite" crystals, mica, and igneous rocks are found between the deposits. These types of deposit require selective quarrying, which is done to some extent by certain plants, but it is not highly effective as most of the cement plants have no detailed geological and prospection studies on the raw materials. An average analysis of low and high limestone is considered as a raw mix in some of the plants, but it requires a small percentage of sweetener to correct the raw feed. This sweetener is relatively costly and some plants use lesser amounts. Laterite, clay, sandstone, and iron ore with small percentages are used in some cases as corrective materials. Table 1, on the following page, shows the different raw materials used by each plant visited.

2 Chemical and mineralogical constituents of raw materials: Both are greatly varied and dependent on the amount of impurity constituents. Intrusions of clay minerals, quartz and calcite crystals, and igneous rocks usually exit without order and in different quantities. Calcite mineral is the main constituent of limestone. Free SiO_2 is considered very high in most of the deposits and cannot be easily sorted. $MgCO_3$, Cl

Table 1: Raw materials used by the cement plants visited

Plant Raw Materials	1 M/S Shree Digvijay Cement Ltd	2 M/S Saurashtra Cement	3 M/S CCI Nayagaon	4 M/S Lakshmi Cement	5 M/S Shree Cement	6 M/S Panyam Cement	7 M/S Durga Cement	8 M/S Madras Cement
High Grade Limestone	X	X		X	X	X	X	X
Low Grade Limestone				X	X			X
Feedable Limestome			X		X			
Sandstone	X							
Sweetener								X
Bauxite						X		X
Laterite			X		X		X	
Clay		X						X
Iron Ore						X	X	X
Intrusion and impurities in the limestone deposits								
Quartz	N.A	N.A.	X	N.A.	X	X	X	X
Calcite							X	
Igneous Rocks								X
% of free silica in limestone	N.A.	N.A.	9-11	N.A	3-8	10.80	≃10	4-9

and the minor oxides (SO_3, K_2O, Na_2O) are low and do not attribute to any build-up in the preheater system. It has been observed that most of the plants do not determine the minor constituents of their deposits, nor are they aware of the mineralogical composition.

3 Crushing system: In some plants, the crusher capacity is not sufficient to supply the required crushed feed to the plant. In other plants, the limestone is crushed to a small particle and creates more dust. The wear is also high due to the presence of quartz in the limestone. The crushing system is not designed for picking up impurities (such as quartz), except in one plant where the igneous rocks are picked by hand.

4 Raw materials handling: Some of the cement plants have several problems in handling their raw materials, especially in the winter rainy seasons, as a cover is not provided for raw materials storage. Also the size of the belt conveyor or aerial rope-ways used to convey the crushed limestone is not sufficient for the plant capacity.

5 Preblending of raw materials: Although some of the visited plants have a preblending system, they are not working efficiently, and in general, it can be said that these plants have no preblending system, which is considered as an essential piece of equipment for Indian cement plants due to the wide variations of the limestone deposits and the use of several components of raw materials.

6 Raw materials grinding: In some plants the capacity of the ball mill(s) is not sufficient to grind the required raw meal to feed the kiln. The ball charge and its distribution are not suitable to the materials feeding to the mill. This results in low production, high fineness on 170 and 72 mesh and high kwh/t. Some plants are not provided with weight feeders to adjust the feed amount. Drying of the feed in a ball mill in some plants is incapable of producing a product with low moisture, due to insufficient hot gas and/or the system cannot handle a large amount of gases (one fan system). In the case of vertical mill, wear of the rollers is high due to the presence of a high amount of quartz in the raw materials. Kwh/t of raw feed reaches over 65 in one of the cement plants visited and is higher than that of the cement mill of the same plant.

7 Blending system: Generally speaking, it can be said that all the cement plants visited have no efficient blending system. The mill product is fed to the kiln without efficient homogenization and with a large variation in $CaCO_3$ content that reaches more than 1% in the 24 h. One plant can control the kiln feed, although it does not have an efficient

blending system, by controlling the weight feeders, regular sampling and regular analysis using X-ray fluorescence. Other plants fail to control the kiln feed due to their poor quality control and raw mill system.

8 Chemistry and fineness of raw mix: Few plants are capable of feeding the kiln with a raw mix that can produce a clinker of good quality after burning coal with approximately 30% ash. Others feed the kiln with chemically unbalanced meal that produces clinker of inferior compositions (according to Bogue calculations). Free SiO_2 in some raw mixes reaches more than 80% of total SiO_2 of the feed. S.M. and A.M. of the kiln feed are low due to the effect of coal ash contribution, but in the clinker are relatively high. L.S.F. of the kiln feed differs from one plant to another, but in general it is low as the amount of high grade limestone used is low and/or the amount of low grade limestone used is high. In some plants, the raw mix design is not balanced well to produce a high quality of clinker considering the ash absorption. This is due to poor quarry operation, not sorting and removing low-grade limestone, with the objective of decreasing the cost. The quality control is considered poor. The minor constituents are never performed on the raw mixes, as a regular checkup, although it is shown that they are small amounts. They do not cause any build-up problems in the cyclones. Although free SiO_2 is high in some plants, yet no provisions are provided for such a mix, by using high amount of fluxes or grinding the mix finer. Most of the plants do not limit the amount and size of free SiO_2 (and or calcite) which can be tolerated in their raw mixes to produce the maximum kiln production--quantitatively and qualitatively. Only one plant has limited the maximum amount of the impurities (igneous rocks) that can be tolerated.

Fineness of the kiln feed in most of the plants is very high on both 170 and 72 mesh. Considering that and variable $CaCO_3$ and chemical constituents, therefore, instability of kiln operation, variable clinker quality with inferior properties and high free lime producing cement with high expansion are encountered with most of the cement plants. Calcination of the precalciner in some plants is affected by that resulting in variable calcination. Most of the cement plants lack the understanding of free silica, limits of the particle size of the kiln feed and the effect of free silica on burnability and kiln production. They also lack the burnability test, which should be done to determine the mix components and parameters, when the deposits are changed. Table 2, on the following page, shows the raw mix properties, percent of dust and energy consumption for the different cement plants visited.

Table 2: Raw mix properties, % of dust and energy consumption

Plant	1	2	3	4	5	6	7	8	
Raw Mix Composition %								Burning	
								Easy	Hard
SiO_2	12.40%	12.0-12.6%	12.64%	11.65%	11.64%	12.00%	12.84%	11.81%	11.86%
Al_2O_3	3.65	3.2- 3.8	3.62	4.00	4.02	2.66	3.10	2.82	2.76
Fe_2O_3	2.66	2.2- 2.4	3.00	2.31	2.10	2.24	3.13	2.18	2.24
CaO	43.50	44.2-45.0	43.09	44.54	43.19	45.08	44.17	45.07	44.81
MgO	1.30	0.6- 0.8	0.98	1.00	1.93	1.07	0.67	1.90	1.90
SO_3	0.15	0.2	-	0.15	-	0.15	-	-	-
K_2O	N.A	N.A	-	N.D.	0.68	0.30	0.18	-	-
Na_2O	N.A	N.A	-	N.D.	0.28		0.08	-	-
LOI	35.45	35.2-38.5	34.86	35.64	35.35	35.94	35.42	36.06	35.60
Total	99.11	-	98.19	99.29	99.19	99.45	99.59	99.84	99.17
S.M.	2.00	1.9- 2.2	1.9- 2.1	1.84	1.90	2.45	2.06	2.36	
A.M.	1.37	1.4- 1.6	1.07-1.17	1.73	1.91	1.19	0.99	1.24	
H.M.	2.35	-	2.0- 2.35	-	2.43	2.67	2.32	-	
L.S.F.	107.0	-	95-105	114.0	111.0	117.9	105.0	119.0	
Free Silica	N.A.	N.A.	6.9-9	(6-8)	≃8	≃10	≃ 9.9	5.5-6.0	
T.C.	≃ 77.34	78.6-79.2	≃ 79.0	≃ 77.0	≃77.0	79.5-80.5	79.0%	77.25-78.00	
Fineness + 170 mesh	22-24	18.0	17.0-19.0	16-18	14.16	19-23	15-20	14-16	
+ 72 mesh	-	40	2.0-2.5	2.5-3	1.6	3-4.8	3-4	1.6-2.0	
%of dust	10	12-15*	(7-10)	N.A.	7-8	10	19-20	7-8	
Heat consumption kcal/kg	790-820	875-890	900-910	900-950	800	1,050-1,150	950	950	
Power consumption kwh/ton	115	130	142-150	115	110	175	130-133	105	

* 8% when Mill is working. N.B. : List of plant names is given on page 10.

9 Rotary kiln instrument and control: A few cement plants have an adequate process control (although it is not updated) and most plants are poor in process control and instrument for kiln operation. Some of the equipment which is available for the kiln is not operating due to maintenance reasons or for lack of spare parts. No plant is working with X-ray analyzer on line. Only one plant has an X-ray (fluorescence and diffraction) for raw materials, kiln feed and clinker analyses. Air leakage and poor kiln inlet and outlet sealings are common in all the plants visited. No hydraulic system is provided to any plant to control the kiln moving. Monitoring of sintering process and temperature is not available in any plant. Amount and temperature of air (primary and secondary) to the kiln cannot be measured or controlled in most of the plants. Equipment to control the cooler is also poor. All these added to variable quality and unbalanced kiln feed, low quality of coal, inconsistent and high fineness, will result in upsetting the kiln performance, unstability of the kiln coating, brick deteriorating, variable quality, high free lime and high fuel and energy consumption.

10 Coal quality: Variable coal quality, with high and variable ash (reaches to 40%) and moisture contents, inconsistent and low heating value (reaches to below 4,000 kcal/kg) is usually used to fire the kiln. No blending system is available to homogenize and blend the coal in all the cement plants, and there is not enough capacity to dry most of the moisture in the coal. In some plants, 8% moisture in the coal is fed to the kiln. Coal is used without analysis or characterization in order to adjust the kiln feed. Coal fineness is not adjusted (for kiln and PC) to maximize coal flammability and efficiency. Coal with about 18% residue on 170 and 3% on 72% mesh is used for firing. Primary air varies and O_2 at kiln inlet and ID fan is high.

Coal ash is very high and its constituent is variable. No analysis is performed regularly on the ash, in some plants, to adjust the kiln feed. This results in variable production and instability of the kiln, and ring formation in the preheating zone. Table 3, on the following page, shows coal and coal ash properties, fuel consumption and percent of ash absorption for the plants visited.

11 Coal firing system: All the kilns use indirect firing system. Most of the flame is impingement, which may be due to unsuitable particle size of coal, design of the burner pipe, moisture in coal and/or primary air percent. Hot gases for the coal mill in some plants are not capable of completely drying the coal, resulting in feeding the kiln with moist coal. Some plants are suffering from low coal supply.

Table 3: Coal and coal ash properties, fuel consumption and % ash absorption

Plant	1	2	3	4	5	6	7	8
Coal Properties:								
Moisture %	2.5-3.5	N.A.	1-3	2.28	3.0	4-8	5.74	3.0-5.0
Ash Content %	28-31	27-30 (40)	29.5-35.5	29.5	29.23	34-37	30.50	30-42
H.H.V. kcal/kg	4,800	4,700-4,900	4,700	-	4,452	3,800	5,380	-
L.H.V kcal/kg	4,000	-	3,600	-	-	3,500	4,200	-
Usable H.V kcal/kg	-	-		4,509	-	-	-	-
Coal Consumption %	≃ 20	≃ 8	≃ 20	≃ 20	≃ 20	26-28	≃ 20	≃ 20
% Coal Fineness 170	10.0-12.0	12.8-18.0	15.0-16.0	13-15	15-16*	20-24	18-20	15-20
72	-	-	1.0	-	0.6-0.8	-	2-3	3
Ash Analysis								
SiO_2 %	58.0-60.0	58.0-62.0	56.0-60.0	58.00	61.34	62.60	57.14	62.46
Al_2O_3 %	25.0-28.0	23.0-25.0	24.0-28.0	24.5	25.80	23.00	26.84	22.57
Fe_2O_3 %	5.0-7.0	6.5-8.5	2.8-6.0	9.30	7.20	3.88	6.82	7.97
CaO %	-	5-9	5.2-9.5	6.17	2.00	3.32	2.06	4.22
Others %	10			3	4	7.20	7.00	4.55
% Ash Absorption	≃ 5	≃ 5	≃ 5.5-6.4	5-6	≃ 5	7-9	6.86	6

* For PC: 22-24%

N.B. : List of plant names is given on page 10.

12 Fuel and power consumptions: In most of the plants, the fuel consumption is considered high due to the above-mentioned variables. In one of the plants, it reaches 950 kcal/kg using the suspension preheater system, although there is no bypass provided. All the cement plants visited have no bypass equipment. The power consumption in most of the cement plants (except Madras Cement Company) is relatively high. In one plant, it is about 175 kwh/t cement.

13 Dust and conditioning tower: All except one of the visited cement plants have a high amount of emitted dust (reaches about 20% in one plant). Some amount of this dust is collected, while the rest is lost. In most of the plant, the collected dust is fed to the kiln together with the mill product without blending, which causes instability of the kiln operation. Some kilns are provided with a conditioning tower, while others are not. Water used to cool the exhaust gases in the conditioning tower, in some plants, is not sufficient; besides it is not suitable to be used. Efficiency of the conditioning tower in some plants is poor. Only one plant has 7 - 8% dust, which is collected and returned back to the system. This plant has clean air. No study has been done on any plant on the different dust collected from different points, with regard to its chemical and mineralogical analyses, its quantity and its effect on the kiln operation.

14 Clinker quality: Clinker produced in each plant is variable in composition and quality. In general, the clinker is characterized by low S.M. The A.M., which varies from 1.05 - 2.09, H.M. is also variable and in most of the cases it is in the low range, as well as L.S.F. and C/S indicating underlime raw mix. C_3S is low and C_2S is high. C_3S/C_2S ratio reaches to 0.66 (CCI Nayagaon) according to Bogue calculation; which is not a normal practice. In most of the plants, except Madras cement company, this ratio is less than 2. The liquid phase is also variable and ranges from 26.6 - 33.6%. In some plants, free lime reaches 3.5% with high expansion in the produced cement. Table 4, on the following page, shows the clinker analysis of the eight cement plants visited and the properties of each.

It is well understood that the Bogue formulae are only theoretical calculations. The best approach to mineralogical composition of the clinker produced is using the miscroscope techniques; which is not utilized by any of the visited cement plants. Most of these plants are not aware of this technique.

Table 4: Clinker analyses of the cement plants visited

(Percent by weight - plant analysis)

Constituents %	Shree Digvijay Cement Sikka	Saurashtra Cement Ranavav	CCI Nayagaon	Lakshmi Cement Banas	Shree Cement Beawar	Panyam Cement Cement Nagar	Durga Cement Works Durgapuram	Madras Cement Ramaswmay
SiO_2	21.35	21.90	23.74	20.98	21.20	22.75	22.52	21.46
Al_2O_3	6.36	5.80	5.24	6.95	6.90	5.17	5.90	5.99
Fe_2O_3	4.20	3.40	5.00	3.50	3.30	4.60	4.60	3.04
CaO	64.15	64.95	62.59	64.58	64.00	64.02	64.40	65.46
MgO	2.00	0.95	1.20	2.08	2.12	1.25	1.42	2.04
SO_3	0.30	0.33	N.A.	N.A.	N.A.	N.A.	0.67	Trac.
K_2O	N.A.	N.A.	N.A.	N.A.	0.92	0.50	0.36	Trac.
Na_2O	N.A.	N.A.	N.A.	N.A.	0.42		1.08	Trac.
L.O.I.	0.40	0.60	0.92	0.57	0.50	-	-	0.74
Total	98.76	97.93	99.1[illegible]	98.66	99.42	98.29	100.95	98.73
C.L.W.	1,300	1,180-1,470	1,050-1,300	1,250-1,300	1,220	1,050-1,250	1,150	1,250
F.L.	2.0	1.5-3.5	0.5-1.0	2.1-2.5	1.68-3.0	0.8-1.0	0.76	2.0
S.M.	2.02	2.38	2.32	2.00	2.08	2.33	2.14	2.37
A.M.	1.51	1.71	1.05	1.98	2.09	1.12	1.28	1.97
H.M.	2.01	2.09	1.84	2.06	2.04	1.97	1.95	2.15
L.S.F.	0.92	0.92	0.82	0.91	0.92	0.88	0.88	0.95
C/S	3.00	2.97	2.64	3.08	3.01	2.81	2.86	3.05

Table 4 : Cont.

Constituents %	Shree Digvijay Cement Sirra	Saurashtra Cement Ranavav	CCI Nayagaon	Lakshmi Cement Banas	Shree Cement Beawar	Panyam Cement Cement Nagar	Durga Cement Works Durgapuram	Madras Cement Ramas-wmay
Potential Composition*								
C_3S	45.17	45.01	29.94	43.57	40.25	44.24	42.70	54.66
C_2S	27.39	29.09	45.67	27.53	30.66	32.11	32.60	20.59
C_3A	9.75	9.62	5.43	12.50	12.71	5.92	10.50	10.73
C_4AF	12.78	10.35	15.22	10.65	10.04	14.00	14.00	9.25
Liquid Phase	30.27	26.59	28.69	31.39	31.37	27.34	33.63	26.61
C_3S/C_2S	1.65	1.55	0.66	1.58	1.31	1.38	1.31	2.65

* Theoretical calculations based on Bogue formula.

N.B.: 1 0.80% total alkalies was considered for liquid calculation, in the case where it is not determined.

2 An average percent of free lime was deducted from total CaO for Bogue calculations.

3 N.A. means not available.

15 Sampling system: There is no continuous sampling system. The sample is picked up and grabbed at a certain time, which does not represent the actual material. In this respect, it is recommended to utilize a continuous sampling system, especially for the kiln feed.

16 Quality control and lab equipment: In general and in most of the visited plants (except Madras Cement), the quality control is poor. The lab rooms and equipment are dusty and old. Madras Cement has a modern X-ray equipment (computerized X-ray fluorescence and diffraction). It is recommended that the cement plants should modernize their equipment and utilize a modern lab facility.

17 Material and heat balances of the plant: Most of the plants are not aware of the material and heat balances on which the design of the equipment was established. These data are essential for the production personnel to adhere to the designed values. Also, the raw mix guides by the equipment supplier should be followed. If this cannot be achieved, burnability tests should be performed on different raw mixes until the optimum is obtained.

D. Results of the findings and their utilization

After visiting each plant, a report was wirtten including the recommendations which should be taken place to improve and enhance the plant productivity. This report will be sent to the plant management through the National Council. These recommendations were given based on the data obtained from the plant personnel and they should be followed and they are for short and long terms. The short-term recommendations include immediate actions to improve the raw mix design, its burnability, coal quality, kiln operation, etc. Long-term recommendations include complete study and evaluation of the raw material deposits, quarry operation using selective raw material technique, erecting different equipment such as preblending, high efficient blending system for kiln feed, blending system for coal, rehabilitate the plant, etc.

E. Raw mix designs and clinker quality

Most of the raw mixes used by the cement plants visited produce underlime clinker. There is a possibility that C_5A_3 is formed which on cooling reacts with C_3S phase, extracting CaO by surface reaction and thus forming C_3A and C_2S. Both encapsulate the C_3S or C_2S in case of large balls. Such a clinker is relatively harder to grind than the new clinker.

A.M. in the clinker varies, but it is recommended to have A.M. low. A.M. in excess of about 1.8 should be avoided if such mixes can be uneconomically produced. High amount of Fe_2O_3 is not a detrimental factor in the sale of a relatively dark cement. It must be considered that the A.M. attributes to controlling the burnability index of the raw mixes.

All the produced clinker contains free lime. The outer section of the clinker is heated to a higher temperature than the core and the uncombined CaO, as a result will be centralized in the inner section rather than in the outer shell. Therefore, depending on the mix design, clinker size and the amount of free lime in the average of the clinker ball, the clinker compositions throughout any individual clinker ball is varied. An average C_3S/C_2S of 2 should be considered for the clinker. The lower the ratio, the greater the tendency for the C_2S to interfere with the normal hydration of C_3S.

Raw mixes designed with low C_3S gives a clinker with rather high free lime value and inferior properties in the resulting cement. The larger the clinker ball, the higher free lime and the worse is this situation. This situation is further greatly aggravated in coal-fired kilns, because of improper coal fineness, high ash content, lack of sufficient draft due to obstructions in the kiln, and insufficient blending system. In this case, a substantial portion of the coal ash falls on already partially formed clinkers in the burning zone. It is then necessary to force the low refractory coal ash shell into the interior of the primary clinker mass in order to establish homogenity. Since the raw mix is designed to neutralize this effect, the burning effort usually fail. This results in a high free lime, which will result in effort in increasing in the burning zone temperature merely introduces more coal ash into the mix, thus tending to increase clinker ball in size. Using dust with the unhomogenized kiln feed, without blending will worsen this condition. Raw mix containing variable amounts of dust in the absence of prior satisfactory blending is considered deleterious to clinker quality.

In the case of "batch nonuniformity" clinker with substantial quantities of low C_3S/C_2S ratio is produced. The coal ash is concentrated at the outer shell, whereas the core volume with its high free lime demanding the SiO_2, Al_2O_3 and Fe_2O_3 from the ash for reaction. The outer shell becomes low in free lime, while the core contains a considerable amount of free lime and is practically free of coal ash. A substantial portion of such a clinker (especially big balls) is characterized by extremely low C_3S/C_2S ratio. Such properties are encountered with many cement plants visited, where the C_2S is encapsulated by a layer of C_3S.

It is essential to produce small clinker and this can be achieved by controlling the mix components and the burning techniques. Small clinker balls with acceptable uncombined lime content for properly designed mix constituents, is the first step in any operating series for the production of high grade portland cements. C_3S/C_2S should be restricted to a minimum so that their detrimental effects on cement quality will be practically negligible.

It is preferable to keep the A.M. at about 1.38 in the case of using considerable amount of free SiO_2 (particle size of SiO_2 is important). This value gives assurance that the liquid phase will be neither over or underlimed, assuming the mix is well designed. The liquid phase should be kept in the range of 28%, otherwise the clinker can be harder to grind and increases the possibilities of ring formations if it is increased.

F. Establishment of a data base at NCB for monitoring the various productivity indicators

This subject has been discussed with NCB and a format for establishment of such a data bank based on the microscopic structure of the clinker was prepared, and is contained on page 34. This data includes the correlation between the clinker constituents (using the microscope techniques), the raw mix composition, clinker production process, kiln parameters, cooler type, flame shape, coal properties, particle size of kiln feed and coal, etc. In this respect, it is recommended to send a questionnaire to each plant to obtain the data required with a representative sample of the clinker. All this information with the results of the microscopic examination of the clinker can be stored in a data bank managed by NCB. Any change in the clinker structure and/or kiln operation can be monitored by NCB.

G. Expert appraisal, NCB format

Annex 10 shows the NCB format for expert appraisal for all the cement plants visited. These forms were filled and were delivered to NCB.

H. Conclusions

The raw materials used for cement production for the eight plants visited are heterogeneous and vary from low grade to high grade limestone. The low grade contains clayey materials and veins of quartz and/or calcite crystals. Quartz and calcite crystals also are found between high grade limestone. A reasonable amount of low grade is wasted to obtain the required high grade limestone. All the raw materials contain a high amount of free SiO_2 and in some deposits calcite crystals and/or igneous rocks. These materials make the mix hard to burn and the amount of the impurities (free SiO_2 and igneous rocks) cannot be controlled because most of the plants have no complete geological studies on their deposits. The minor constituents (Cl, SO_3, Na_2O and K_2O) are minimum and do not create any problem for dry process using preheater system.

Data Bank
Microscopic Analysis of Clinker
Kiln Evaluation

- Plant name and location: ______________________________
- Kiln identification: ______________________________
- Type of kiln: Preheater with ____ or without ____ flash calciner
  Process: semi dry ____ dry ____ wet ____
- Kiln dimensions: diameter ____ m, length ____ m
- Coal burned: Particle size% 170 _____ 72 ____
  Coal ash % ____
  Moisture % ____
  Sulfur % ____
- Burner-tip velocity: ____ m/sec.
- Position of flame (parallel to load and _____ meters from it; if not parallel, at what angle? _____)
- How far is flame tip from discharge end of kiln? ____ mt.
- Flame configuration: bushy ____ long ____ short ____ sharply tapered ____
- Percent primary air: ____ percent secondary air: ____
- Estimated maximum temperature: ____°C
- Length of cooling zone (distance from approximately midpoint along length of the flame to the nose of the kiln ____ m; temperature of clinker as it leaves kiln ____°C
- Transit time of kiln feed through kiln: ____ min
- Type of cooler: ______________________________
- Clinker production for kiln at time of sampling: ____ tons/day
- Percent oxygen in exit gases: ____
- Visual condition in kiln: dusty ____ moderately dusty ____ clear ____
- Clinker grindability: easy ____ moderately easy ____ difficult ____ very difficult ____
- Percent raw meal on No. 170-mesh sieve ____ 72-mesh sieve ____
- Raw mix analysis: ______________________________
- Cement strength: ______________________________

It is not a custom to have an efficient preblending system, which is an essential piece of equipment, due to the heterogenity of the raw materials. Some plants have a preblending system, but it is poor in homogenizing the crushed limestone. The raw materials are ground coarser than usual. The blending system, if it exists, is not working satisfactorily resulting in feeding the kiln with variable percentages of $CaCO_3$, impurities and residues on 170 and 72 mesh. These cause unstable and erratic kiln operation.

In most of the plants, the process control of the plant is poor. High amounts of leakage air exists with inefficient kiln sealing (inlet and outlet). The instruments controlling the kiln operation are not working. All these result in high fuel consumption and variable degrees of calcination.

The coal is variable with high ash contents reaching to over 40%, resulting in low heating values. It is ground coarser and fed to the kiln without blending and contains a high moisture content. High percentage of primary air is encountered with high O_2% at kiln inlet and I.D. fan.

Kiln operation is unstable resulting in inferior cement quality combined with high free lime and C_2S and low C_3S contents. The quality control in most of the plants visited--except Madras Cement Company--is considered poor. Dust emitted highly exceeds the designed parameters. The dust is added to the kiln feed without blending.

Power interruption is common in most of the cement plants and it accounts for about 80% of the down time. Maintenance is poor (except Madras Cement Company) and power consumption in most of the plants is high. The flame shape, in most of the plants, is lazy and long (due to high ash content of the coal) and is impingement. The coal firing nozzle is not adapted for the useable coal. Secondary air temperature is low and the clinker exit the cooler has high temperature.

The National Council for Cement and Building Materials should highly train a select group of his staff on the raw materials technology and the relationship between the raw materials composition and their burnability and kiln performance. This training can be taken on a regular basis at International well-known cement plants. Arranging seminars at NCB and inviting different experts on a regular basis, to transfer know-how, must be forseen.

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4. Mr. V. K. Arora
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15. Mr. M. Vasudev
16. Mr. C. D. Elkunchwar
17. Dr. V. K. Mathur
18. Dr. P. Bhaskara Rao
19. Mr. A. Alexander

SHREE DIGVIJAY CEMENT COMPANY LIMITED
DIGVIJAYGRAM
SIKKA (GUJARAT)

Shree Digvijay Cement Company is located at Digvijaygram (Jamnagar) Gujarat. The plant is producing clinker by wet and dry process, where there are no problems from the wet production.

The dry process is a precalciner system of the F.L.S. type with a designed capacity of 2,500 mtpd, which has been obtained. The utilization factor of the kiln is 100% and the plant does not have an alkali bypass.

There is a preblending system to blend the limestone that was operating unsatisfactorily during the visit. The raw materials (limestone and sandstone) are ground in a roller mill provided with multi-cyclones, with a capacity of 220 mtph and consumes 11-12 kwh/t product. The rotary kiln is a converted one of the old existing wet kiln. It has a diameter of 3.75 m (inside the bricks) with 75 m length, designed to produce 2,500 mtpd clinker that can be achieved easily. Burning usually takes place at the nose of the kiln and the coal firing nozzle pipe is straight and can move only about one meter in or out.

Plant Operational Problem: There is only one major problem at Shree Digvijay Cement Company. This problem is the formation of a ring at the junction of preburning and burning zones, a distance of approximately 22 m from the kiln discharge. The ring formation is not a continuous process, as it comes and goes at different intervals which can reach for several days. The ring is increased in thickness by time to the extent that it prevents flowing kiln feed causing flushing the kiln in some cases, and boulders build up at the back of the ring. In some cases, the ring is not a regular circle and it can be built up leaving an opening of approximately 1 m. Figures 1 and 2 show an approximate location of the ring in reference to the kiln discharge, and a cross section of the kiln at the ring location, respectively. This was observed during the 10 October 1986 visit to the plant.

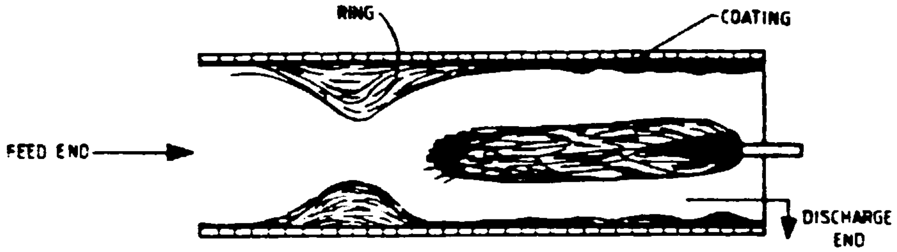

FIG 1 LOCATION OF RING IN THE KILN

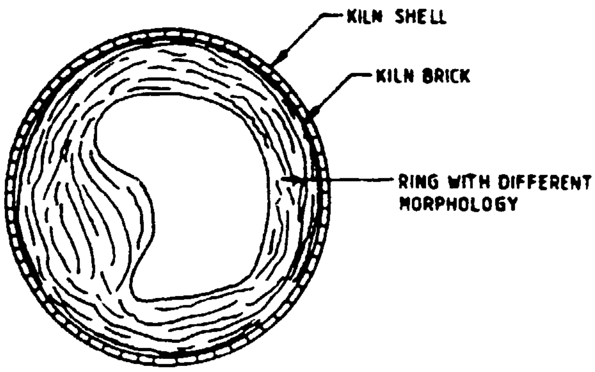

FIG 2 MORPHOLOGY OF RING

The location of the ring formation varies and it is within a distance of 18-24 m from the kiln discharge. It occupies a distance of about 2.0 m and is more or less conical, with maximum coating at the apex, Fig 3.

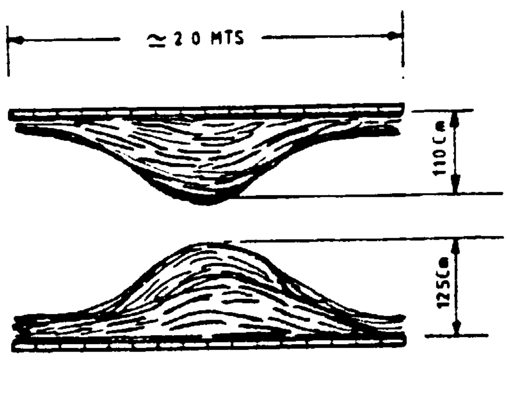

FIG 3 SHAPE AND OCCUPATION DISTANCE OF THE RING

Another build-up, snowman, was noticed at the entrance of the grate cooler. This is not serious and does not cause any stopping.

The following tables show the chemical analysis obtained from the plant for both the ring and coating samples, sampled on 17 July 1986 and 09 September 1986 respectively:

	Ring Sample	Coating Sample
SiO_2	20.48	19.35
Al_2O_3	6.94	6.55
Fe_2O_3	4.76	4.40
CaO	63.50	64.50
MgO	2.36	1.73
SO_3	0.39	1.30
K_2O	N.A.	N.A.
Na_2O	N.A.	N.A.
L.O.I.	1.48	2.71
	99.91	100.54

It was noticed that:

1. raw materials and coal in stock are minimum
2. quite big variations in 24-hour period for:
   a. $CaCO_3$ for kiln feed : can reach 1%
   b. fineness of kiln feed : 25.6 - 18.8% on 170 mesh and 3.0 - 1.07% on 72 mesh.
   c. coal fineness : 29.6 - 12% on 170 mesh and 14.8 - 1.2% on 72 mesh.
   d. as the quality of coal is changed from good to bad, kiln ring is formed
   e. reducing fuel and feed, ring diminishes while increasing fuel and feed ring is formed

A considerable variation and instability in the kiln operation and sintering the kiln feed occur.

Sample Collected and Observations: The opportunity arose to break the ring and to collect several samples when the kiln stopped on 10 October 1986. The samples were characterized and evaluated to take the right and appropriate measurements to prevent ring formation. The sample collections started from the kiln discharge to the ring location and at intervals of 2 meters. Each sample has its peculiarity, but it was noticed that white particles (presumably CaO) is mixed with light brownish powder (presumably coal ash) with different percentages and some other fused constituents. Some of the samples were fragile and easily broken to powder. Three samples were collected from the ring. These are:

a. Top layer: With a thickness of 30-40 cm. The surface is melted and transferred to a glazy layer with yellowish brown in color. It contains some white particles, not on the surface.
b. Middle layer: With a thickness of 60-70 cm, which is mixed between hard brown material and some soft powder.
c. Bottom layer: With a thickness of about 15 cm laying above the bricks. It is a soft material brown in colour.

Reasons for Ring Formation: It is difficult to give a definite reason(s) for the ring formation at Shree Digvijay Cement without analyzin the samples carefully and studying the results. However, due to the inconsistent kiln feed (quality and quantity), coal (quality and quantity), flame shape, using the dust from different sources without blending it with the kiln feed in an acceptable way, etc., all these factors combined upset the kiln operation. This will result in increasing and/or decreasing the coal and accordingly the kiln feed and variations in the operational parameters. Consequently, the coal ash is increased or decreased as well as the $CaCO_3$. Considering this is a dry process having unhomogenized dust in the feed, it seems probable that C_2S may from very early in the kiln and may thus initiate spurrite ($2Ca_2SiO_4 \cdot CaCO_3$) formation. Spurrite formation causes ring formation and it is considered that low-melting alkali/calcium carbonates ($R_2Ca(CO_3)_2$) form and promote the formation of spurrite when the cold incoming charge material builds upon them. It is considered that spurrite formation is due to faulty control of burning conditions. It is expected some other intermediate compounds such as gehlenite (C_2AS), enstatite, kaliophyllite (KAS_2), $C_{12}A_7$, C_2S and C_3S and/or other compounds may be formed at this location. However, by XRD, the mineralogical constituent of this ring will be identified and a clear picture will be drawn out.

Another factor that can contribute to the ring formation is the diameter of the kiln, which is considered small with a bigger length. This was an existing kiln, which was producing clinker earlier through wet process. It may be considered less calcination in the PC, with improvement in the sintering process, flame shape, coal combustion with the exact amount and right proportion of air, etc.

Evaluation of the Kiln Feed: The proportion of the raw materials (according to the plant information) shows that it is different than 97% limestone : 3% sandstone. This change probably is due to the effect of the dust added. However, this feed is as follows:

	Kiln Feed	LFRM	95% LFRM + 5% Coal Ash*
SiO_2	12.40	19.48	21.46
Al_2O_3	3.65	5.74	6.78
Fe_2O_3	2.66	4.17	4.26
CaO	43.50	68.33	64.91
MgO	1.30	2.05	1.95
SO_3	0.15	0.23	0.30
K_2O	N.A.	N.A.	0.34
Na_2O	N.A.	N.A.	
LOI	35.45	-	-
Total	99.11	100.00	100.00**
S.M.	1.96	1.96	1.94
A.M.	1.37	1.37	1.59
H.M.	2.35	2.33	2.00
L.S.F.	107%	107%	91.60%
CaO/SiO_2	3.51	3.51	3.03
C_3S		80.86	48.64
C_2S		(-5.15)	12.88
C_3A		8.16	10.76
C_4AF		12.69	12.96
L.P.(1400°C)***		28.15	31.32
C_3S/C_2S		-	3.78

* Does not include alkalies content.

** Assuming that the coal has 30% ash content, which will contribute about 5% to the clinker.

*** Does not represent the correct figure, as some analysis data are missing.

The theoretical analysis (95% LFRM + 5% coal ash) is more or less similar to the one obtained from the plant, which is shown in the information collected. The S.M. did not change than the LFRM, while the A.M. has increased. H.M., L.S.F. and CaO/SiO_2 decreased as well as C_3S. C_2S reached to 12.88, C_3A increased as well as the liquid phase. The S.M. is low (R_2O_3 is relatively high) as well as CaO shows relative deficiency (91.60% L.S.F. and 2.00 H.M.), which can result in an increase in the C_5A_3 in the liquid in burning zone. C_3S/C_2S in the clinker is 3.78, which is considered a relatively high ratio.

Such a raw mix is unbalanced as the modulus of the produced clinker (95% LFRM + 5% coal ash) and its composition do not match each other. It is highly recommended in this respect to adjust the mix so that after considering the ash contribution, the final clinker should be within the following limits:

S.M.	2.3 - 2.4
A.M.	1.3 - 1.4
H.M.	2.1
L.S.F.	92 - 95%
CaO/SiO_2	3.15
C_3S	52 - 55
C_2S	20 - 25
L.P.	$\simeq$28%
C_3S/C_2S	$\simeq$2.5

These changes should not be at the expense of the volatile materials in the raw mix.

Effect of Using the Dust: As it was mentioned early, the dust collected from different sources (raw mill, I.D. fan and conditioning tower) are collected and supplemented to the kiln feed without blending. This will result in producing inconsistent kiln feed and clinker balls with varied C_3S/C_2S ratios. This situation is further aggravated in the rotary kiln by coal firing, because of variable quality, improper coal fineness, high ash content, lack of sufficient draft due to obstructions in the kiln and insufficiency of primary air, causing a substantial portion of the coal ash to fall on already partially formed clinkers in the burning zone. It is then necessary to force the refractory coal ash shell into the interior of the primary clinker mass in order to establish homogenity; since the raw mix is designed to neutralize this effect and therefore is distinctly overlimed, the burning effort to achieve the desired aim frequently results in failure. This failure manifests itself in an average high free lime content (which is a fact, as about 2% free lime is obtained from the clinker with 92% L.S.F.). An effort to reduce the free lime by an increase in the burning zone temperature merely introduces more coal ash into the mix, thus tending to increase the size of the clinker and therefore the resistance to heat penetration. This constitutes a complex cycle of thermal reactions, and results in upsetting the kiln performance and clinker quality.

Recommendations:

1. Adjust the kiln feed as previously mentioned
2. Feed the kiln with consistent kiln feed (±0.2% $CaCO_3$ and about 15% residue on 170 mesh), taking into consideration the dust added, quantitatively and qualitatively.
3. Dust, in the case of its use, should be blended with the mill product in the blended silo. No dust will be allowed to feed the kiln without blending. Dust handling should be engineered carefully.
4. Coal should be blended and a supply for 10-15 days should be available. Characterize the coal before feeding it into the kiln and/or preclaciner and adjust the kiln feed accordingly. Coal with ash less than 30% is highly recommended.
5. Particle size of kiln feed and coal should be adjusted to the optimum. Coal with different particle sizes to PC and kiln may be required.
6. Determination of minor constituents is requested on a regular basis for raw materials, kiln feed, clinker, coal, and coal ash.
7. As the kiln is long and small in diameter, trials are requested to keep calcination in the precalciner at 85% (or slightly less), and pushing the flame nozzle inside the kiln. Optimum operation to be followed.
8. Flame shape required to be adjusted using adequate coal fineness, the correct amount of primary air, and avoid flame impingement.
9. It is required that a good process control be established in the plant with an X-ray spectroscopy for kiln feed analysis. It is preferable to use CaO content rather than $CaCO_3$ content.
10. It is recommended to improve the quality control and pay more attention to the plant maintenance.
11. Dust from different collecting points should be completely analyzed for alkali, carbonates, Cl, SO_3 etc. Its quantity also should be determined.
12. Effect of coal-ash contribution (quantity and quality) on the kiln feed quality and its burnability is recommended to be studied.
13. It is highly recommended to study the clinker by microscope techniques, to evaluate the crystals' shapes, sizes, burning and cooling processes and relate these to the cement properties. Optimum quality and operation can be obtained by this study.
14. Although the power consumption of 115 kw/t of cement is a good figure for a dry process, it is recommended to have an energy audit through all the plant to study possibilities of saving energy at different production points.

<u>Other Subjects Discussed</u>:

1. Oil Well Cement : Including chemistry and properties
2. Type V Cement : Raw materials and its production
3. Clinker Microscopy: And its relation to the clinker quality

SHREE DIGVIJAY CEMENT

Information Collected

Raw Materials: Limestone and sandstone.

- Limestone is soft with 5 - 6% moisture, 28% porosity, and about 8.4% free SiO_2. It has 10.50 B.W.I., 0.004% Cl, 0.20% Na_2O and 0.14% k_2O.
- Sandstone is unusually hard and 5 - 6% moisture

	Limestone	Sandstone
SiO_2	11.30	84.60
Al_2O_3	3.67	10.20
Fe_2O_3	3.00	1.60
CaO	45.03	2.00
MgO	1.30	Traces
SO_3	0.10	-
L.O.I.	35.50	2.30
Total	99.80	100.70
Free SiO_2	N.A.	N.A.
Total Alkalies	$\simeq$ 0.20	N.A.

Kiln Feed: 97% limestone : 3% sandstone

SiO_2	12.40
Al_2O_3	3.65
Fe_2O_3	2.66
CaO	43.50
MgO	1.30
SO_3	0.15
L.O.I.	35.45
Total	99.11
S.M.	2.00
A.M.	1.37
H.M.	2.33
L.S.F.	1.06
Fineness	22 - 24% on 170 mesh
$CaCo_3$	77.34%
Free SiO_2	N.A.

Clinker:

SiO_2	21.35
Al_2O_3	6.36
Fe_2O_3	4.20
CaO	64.15
MgO	2.00
SO_3	0.30
L.O.I.	0.40
Total	98.76
S.M.	2.02
A.M.	1.51
H.M.	2.01
L.S.F.	0.91
F.L.%	2.0 (F.L. is usually high)
C.L.W.	1,250 - 1,350

Kiln Capacity : 2,500 mtpd

Utilization Factor : $\simeq$100%

Process : Dry process with F.L.S. precalciner

Alkali Bypass : No

Type of Cooler : Grate cooler

Fuel Splitting : $\simeq$ 33% - 67% (kiln : precalciner).

Fuel : Coal, with 2.5 - 3.5% H_2O,
28 - 31% ash,
4,800 kcal/kg H.H.V.
4,000 kcal/kg L.H.V.

Firing System : Indirect

Particle Size of Coal : 15 - 10% on 170 mesh

Coal Ash Analysis	: SiO_2 58 - 60
	Al_2O_3 25 - 28
	Fe_2O_3 5 - 7
	SO_3 1 - 1.5
	Others 7 - 8
Fuel Consumption	: 790 - 820 kcal/kg
Lifetime of Bricks	: Six months
Kiln Coating	: 20 - 30 cm, stable
% of Kiln Dust	: 10
Burning Temperature	: 1,350 - 1,400°C
Kiln Back End	: With 950 - 1,000°C temperature
I.D. Temperature	: 300 - 310°C
Dust Collector	: ESP
Is Dust Usable	: Yes, recirculated along with kiln feed
Clinker Quality	: Min. -3mm : 20%
	Max. 100mm :
	kw/t cement : 35
Total kwh/t Cement	: 115 at 3,500 cm^2/gm
Production Problems	: Ring formation at the junction of preburning zone and burning zone. It is 20m from kiln outlet.

SHREE DIGVIJAY CEMENT COMPANY LIMITED
DIGVIJAYGRAM

Names of persons who participated in discussion from Shree Digvijay Cement.

1.	Mr. R.K. Gattani	Vice President (Tech)
2.	Mr. M.L. Govil	General Manager (Works)
3.	Mr. S.K. Rathi	Sr. Manager (Planning & Dev.)
4.	Mr. I.K. Awatramani	Manager (Prod. & Quality Control)
5.	Mr. D.M. Lodha	Chief Chemist
6.	Mr. S.M. Khira	Dy Manager
7.	Mr. R.N. Rathi	Coordinating Officer (P & D)
8.	Mr. V.K. Joshi	Dy Chief Burner

Names of NCB Counterparts.

1.	Mr. T.N. Verma	Scientist
2.	Dr. S.N. Yadav	Scientist

SAURASHTRA CEMENT AND CHEMICAL INDUSTRIES RANAVAV (GUJARAT)

Saurashtra Cem at Company is located at Ranavav (Gujarat). The plant is producing clinker by dry process only, using the precalciner technology. The plant was previously producing clinker by Lepol grate kilns which were stopped after the start-up of the precalciner kiln. The precalciner kiln is an S.F. (suspension flash calciner) type of Fuller - IHI with a diameter of 4.2 m and 6.2 m height. The plant is producing 2,500 mtpd clinker. The preheater tower is a single stream and no problem from build-up in the cyclone and/or the S.F., except usual clean-up. No by-pass is provided to the plant.

There is no preblending system for the raw materials (limestone and clay) which are ground in a roller mill with a capacity of 240 mtph; although the clay is quite variable. Continuous blending system is used to blend the raw mill product. Burning takes place usually at the kiln nose and the coal firing nozzle-pipe is straight and is movable inside and outside the kiln. The plant is operated through a control room provided with a process control but not with an X-ray analyzer.

Plant Operational Problems: Although the kiln capacity was achieved and the plant has not encountered build-up in the cyclones and/or the S.F., yet it is suffering from three main problems in production. These are:

1. Build-up on the blades of I.D. Fan: The build-ups are in the form of irregular scales, red brown in color.
2. Variable degree of calcination in the S.F., which varies from 66 to 84%.
3. High degree of free lime in the produced clinker which varies from 1.5 - 3.5% and in some cases reaches 4.0%. Clinker litre weight also varies. Autoclave expansion is high and in some cases out of the specifications.

Chemical Analysis of Kiln Feed: Two different chemical analysis of kiln feed were collected from the cement plant which were analyzed on different occasions and at different places. These are as follows:

	Kiln Feed (1)	Kiln Feed (2)
SiO_2	10.98	13.58
Al_2O_3	2.85	3.05
Fe_2O_3	2.29	2.39
CaO	45.74	43.58
MgO	0.71	0.50
SO_3	0.05	0.08
K_2O	0.54	0.58
Na_2O	0.60	0.32
C	N.A.	0.14
LOI	36.24	35.50
Total	100.00	99.72
Free silica	N.A.	5.35
Cl	0.008	0.015
S.M.	2.14	2.50
A.M.	1.25	1.28
H.M.	2.85	2.29
L.S.F.	128.50%	100.90%
CaO/SiO_2	4.17	3.21

There is too much variation and both samples cannot fit in the range given by the plant, as it is shown in the information collected.

Clinker, Dust and Preheater Coating Analysis: With regard to the above kiln feed samples, different samples were analyzed at the same time and these are:

- Dust preheater exhaust gas and preheater fan coating together with kiln feed 1.
- Clinker and preheater fan coating together with kiln feed 2.

The analysis of these samples is as follows:

	1		2	
	Dust Preheater Exhaust Gas	Preheater Fan Coating	Clinker	Preheater Fan Coating
SiO_2	8.67	16.20	23.00	16.63
Al_2O_3	3.65	7.76	5.43	7.76
Fe_2O_3	2.81	12.99	3.40	11.63
CaO	46.45	33.04	63.78	31.09
MgO	0.48	1.67	0.74	1.27
SO_3	Traces	0.33	0.38	0.31
K_2O	0.48	0.74	0.91	0.78
Na_2O	0.38	0.53	0.44	0.18
C	N.D.	N.D.	0.00	0.16
LOI	36.76	25.79	0.91	30.23
Total	99.68	99.05	99.95	100.11
Cl	0.055	0.310	-	0.17
F.L.			0.72	
S.M.			2.71	
A.M.			1.60	
H.M.			1.95	
L.S.F.			0.84	
CaO/SiO_2			2.66	
C_3S			35.12	
C_2S			42.20	
C_3A			8.64	
C_4AF			10.35	
C_3S/C_2S			0.83	
L.P. (1,400°C)			25.59	

The dust preheater exhaust gas in comparison to kiln feed 1 shows a high percentage of CaO and L.O.I., with consequently low percentage of SiO_2. Usually the dust is different in chemical composition and with low percentage of L.O.I. than the kiln feed. It is always higher in alkalies and SO_3 than the original feed. The preheater fan coating of sample (1) and (2) are more or less similar in analyses except some variation in Fe_2O_3, CaO, Na_2O, K_2O, SO_3, Fe_2O_3 and again in L.O.I. However, both analyses show low percentages of alkalies, SO_3 and Cl which denotes that the build-up on the fan blades is not due to an SO_3/alkali problem. It is quite clear that the fan coating has a very high percentage of Al_2O_3 and Fe_2O_3 than the original started materials - kiln feed, and a quite pit high silica, which explain that this coating material has a higher percentage of argillaceous materials (clay). The clay in the raw mix is very fine. Hence more argillaceous materials will be blown out of the kiln, which can leave a mix feeding the pyro-processing system with high in $CaCO_3$ and accordingly C_3S. Besides the variations of kiln feed in $CaCO_3$ content, another change occurs with the system due to the blown out fine argillaceous materials, which can upset to quite a reasonable degree the calcination in the flash calciner (assuming all the other parameters are constant). This will alter completely the calcining and burning processes, clinker quality and free lime content. The presence of high Al_2O_3 and Fe_2O_3 at high temperature, which are a flux material besides the alkalies will reduce the eutectic point which as soon as the dust is cooled after the entrance to the fan, it can form coating or build-up on the fan blades (assuming that the mechanical and design aspects for the ID fan are correct).

In this respect, it is recommended to use clay which can be ground coarser and/or to add a very small amount of sand. Grinding the raw mix coarser at the expense of reducing the blow-up of the argillaceous materials is not recommended. The objective is to change the temperature profile of the gases going to the ID fan to counteract the fan build-up.

Although the S.M. and A.M. of the clinker are within good limits, the H.M., L.S.F. and CaO/SiO_2 are low. There is a great tendency that C_2S interfere with the normal hydration of the C_3S, which can present an obstacle to the development of desired strength and hydration rate potentials. There is no doubt that relatively low C_3S content and high free lime value are bound to show inferior properties in the resulting cement. An inferior type of raw mix control will account for the inadvertent aspect of the problem and will lead to "non-uniformal clinker." The clinker ball will be characterized by varied volumes of improperly proportioned C_3S/C_2S ratios. This situation is further greatly aggravated in coal-fired kilns, because of coal quality and kiln operation. Efforts to reduce the free lime by an increase in the burning zone temperature (which will increase fuel consumption) will introduce more ash into the mix, thus tending to increase the size of the clinker and therefore the resistance to heat penetration. Inferior mix control, "batch non-uniformity," could very well produce substantial quantities of low silicate ratio clinker and/or unbalanced kiln feed.

For the kiln feed calculations and the ash contribution to the clinker, it is not clear which mix is used from the two different mixes of kiln feed. In this respect it is highly recommended to feed the kiln with homogenous raw mix (including continuous supply of the dust in a homogenous system; if dust content has no negative effect on the pyro-processing system). The clinker produced could be within these limits:

S.M.	2.4 - 2.6
A.M.	1.3 - 1.7
H.M.	2.1
L.S.F.	94 - 96%
CaO/SiO_2	3.15
C_3S	55 - 66
C_2S	20 - 25
C_3S/C_2S	about 2.5
F.L.	about 1.2%

<u>Reasons of Variable Calcination</u>: From the quality of the clinker, it seems that the kiln feed is not blended well and/or sufficiently. Feed with different $CaCO_3$, free SiO_2 and particle sizes has a great effect in unsteady calcination in the precalciner system. It is essential that the raw meal and fuel particles are distributed uniformly and that as a result, the temperature of gas and solid in the furnace is uniformly maintained. This prevents volatile matter normally contained in the raw meal and fuel--such as alkali, chlorine and sulfur--from being evaporated due to overheat. Combustion air for the kiln recuperated from the hottest zone of the clinker cooler is recommended to be at about 1,000°C, whereas combustion air for the flash furnace led through the secondary air duct is 600 - 650°C. This secondary air is mixed with the kiln exhaust gas of below 1,100°C at the back of kiln, and the mixture temperature will be about 840°C. It is advisable for normal S.F. operation, to keep the fuel rate to the kiln constant, while the throughput and burning conditions of the clinker are adjusted mainly by the fuel to the furnace. The fuel to the furnace is adjusted so as to maintain the proper gas and raw meal temperature at the lowest cyclone stage constant.

It is worth mentioning here that burning coals of differing volatile contents can result in a greater temperature difference between the flash furnace exit and the stage IV exit with the greater volatile content coal. Higher volatile coals will burn more efficiently in the flash furnace. As the coal is variable as well as the raw meal, a variation in the calcination is expected. In this respect, it is highly recommended to check the amount of primary air conveying the coal to the burners, as higher primary air can produce higher burner velocity and accordingly can reduce the degree of calcination. This is attributed partly to the burner velocity, as well as to the replacement of heated secondary air by ambient primary air. [illegible]icle size of coal to the furnace can have an effect on the degree of the [illegible]tion.

Recommendations:

1. Adjust the kiln feed, as previously discussed. It is preferable and advantageous to control the mill product, the blended materials and the kiln feed by x-ray spectroscopy rather than the titration method. It is an advantage that the plant has a modern process control, hence x-ray spectroscopy can be attached to it. The fineness of the kiln feed should be adjusted for better quality and less loss through the dust from the argillacious materials.
2. Change the temperature profile of the system for the exit gas to reduce the build-up in the fan.
3. The kiln feed should be blended efficiently and with a variation ±0.2% $CaCO_3$ or its equivalent of CaO.
4. Dust handling should be engineered carefully, so that it will not upset the kiln performance or the clinker quality.
5. The plant usually keeps a coal supply for about 15 days and blends it manually. This is a credit in quality control. Coal should be characterized before its use and adjust the kiln feed accordingly. Coal with lower ash, as well as a blending system to the coal, would be advantageous.
6. Particle size of the kiln feed and coal should be adjusted to the optimum.
7. Study the combustion efficiency by:
   a. Determining the total C in by analysis of the feed and coal and multiplying each by the corresponding rate.
   b. Determining the total C out by analysis stage IV and dust products and multiplying each by the corresponding rate.
   c. Divide total carbon out by total in and subtracting it from 1 and multiply by 100.

   Coal fineness and quality, primary air, secondary air and calcination affect the combustion efficiency. Different trials should be done until the optimum efficiency and calcination can be obtained.
8. Minor constituents should be determined on a regular basis for raw materials, kiln feed, clinker, coal and coal ash. Free lime is important and to be determined at least once,on average sample of each shift.
9. Use the adequate coal size for each of S.F. and kiln and avoid flame impingement.
10. It is highly recommended to improve the quality control with great attention to be paid to the plant maintenance.
11. Effect of coal ash contribution (quality and quantity) on the kiln feed quality and its burnability is recommended to be studied.

12. It is highly recommended to study the clinker using microscope techniques, to evaluate the crystals' shape, size, burning and cooling processes and relate these to the cement properties. Optimum quality and operation can be achieved from this study.
13. Study the chemical and mineralogical variations for both the limestone and clay deposits. Selective quarry may be valuable for constant and smooth operation. Otherwise preblending can be another alternative. Avoid high percentage of free SiO_2.
14. Power consumption is 135 kwh/ton of cement which is considered on the high side. Energy audit is recommended through all the plant to find out the area(s) which can save energy.

SAURASHTRA CEMENT COMPANY

Information Collected

Raw Materials: Limestone and Clay, both are inhomogenous

- Limestone has about 90% $CaCO_3$ and 6 - 7% moisture
- Clay has about 10% $CaCO_3$ and contains about 15% moisture

	Limestone % By Weight	Clay % By Weight
SiO_2	3.0 - 7.0	59.0 - 63.0
Al_2O_3	0.3 - 0.8	12.0 - 15.0
Fe_2O_3	1.5 - 2.2	4.5 - 6.0
CaO	49.0 - 52.0	3.0 - 6.0
MgO	0.65 - 0.95	0.9 - 1.3
SO_3	N.A.	N.A.
K_2O	N.A.	N.A
Na_2O	N.A.	N.A.
L.O.I.	39.5 - 41.4	8.0 - 10.0

Kiln Feed:

	% By Weight		
SiO_2	12.0 - 12.6		
Al_2O_3	3.2 - 3.8		
Fe_2O_3	2.2 - 2.4	S.A.	1.9 - 2.2
CaO	44.2 - 45.0	A.M.	1.2 - 1.6
MgO	0.6 - 0.8		
SO_3	$\simeq$0.2		
K_2O	N.A.		
Na_2O	N.A.		
L.O.I.	35.2 - 35.8		
$CaCO_3$	78.6 - 79.2%		
Fineness	18.0% on 90 microns mesh and 4.0% on 212 microns mesh		
Cl	N.A.		
Free SiO_2	N.A.		

Clinker:

SiO_2	21.6 - 22.2		
Al_2O_3	5.6 - 6.0		
Fe_2O_3	3.2 - 3.6		
CaO	64.8 - 65.1		
MgO	0.9 - 1.0	S.M.	2.3 - 2.40
SO_3	0.3 - 0.35	A.M.	1.6 - 1.80
K_2O	N.A.	L.S.F.	0.90 - 0.39
Na_2O	N.A.		
L.O.I.	0.4 - 0.8		
I.R.	$\simeq$0.50		
F.L.	1.5 - 3.5		
C.L.W.	1180 - 1470		

Process: Dry process with a precalciner system. A roller mill (240 tpd with about 18.0% residue on 170 mesh) for grinding the raw materials utilizing the preheater gases, supplemented occasionally by an air heater. The blending system is a continuous blending-type-system. A single preheater tower provided with a precalciner. The calcination is a Fuller - IHI system with split in fuel approximately 55 : 45; precalciner to kiln. The kiln is 4.2 m in diameter by 62 m in length, with a production capacity of 2,500 mtpd. Coal is provided to both S.F. and kiln with 18 - 12% residue on 170 mesh. Coal is variable in composition, ash content and heating value. Coal is relatively blended by shoveling and a stock for about 15 days is available. Indirect firing system is used for coal firing. There is no problem from the build-up in the preheater tower or S.F., but light cleaning is required twice each shift. There is build-up of hard and scaly like materials on the preheater fan. Calcination in S.F. is variable, inconsistent, fluctuating from 66 - 85%.

Some Operational Parameters:

- O_2 at FC outlet : 4%
- Gas temperature to FC : 650°C
- Gas temperature exit FC : 880°C
- Kiln back end temperature : 1,150°C
- Degree of calcination : 66 - 84%
- ID Fan temperature : 340 - 350°C
- Sintering temperature : 1,400°C

Coal: Ash Content : 27 - 30%, sometimes reaches 40%

L.H.V. : 4,700 - 4,900 kcal/kg

Coal Ash: SiO_2 58.0 - 62.0

Al_2O_3 23.0 - 25.0

Fe_2O_3 6.5 - 8.5

SO_3 0.8%

Fuel Consumption: 875 - 890 kcal/kg Clinker

Kiln Coating: 30 - 40 cm unstable

% of Dust: 12 - 25% without mill operation,
8% with mill operation

Type of Dust Collector: ESP

Dust Collected: When the mill is down, dust collected from spray tower and ESP are added to the blending silo and mixed. When the mill is operated, the dust with preheater gases is used to heat the mill and goes with the mill product.

Clinker Quality: Approximately 10% with less than 1 mm in size and maximum size is 4 - 5 mm. There are clinkers with different qualities, especially the big pieces, as the center (core) has free lime about 5.0% and the external surface has free lime about 2.0%. However, the F.L. is high and reaches up to 5%, but the compressive strength of the cement is 300, 450 and 530 kg/cm^2 for 3, 7 and 28 days.

Clinker Grindability: 38 kw/t cement (closed circuit)

Total kw/t Cement: $\simeq$130 kw at 3,000 cm^2/gm, using closed circuit.

Problems:

1. ID fan build-up
2. Calcination in S.F. is low and inconsistent
3. High free lime in the clinker, with 1,200 - 1,250 C.L.W. Free lime is about 4%, where expansion occurs.

SAURASHTRA CEMENT

Ranavav

Names of persons who participated in discussions from Saurashtra Cement.

1.	Mr. C.B. Kothari	General Manager (Operations)
2.	Mr. Tulsiyan	Dy General Manager (Maintenance)
3.	Mr. M.P. Rai	Chief Process Manager
4.	Mr. P.N. Dave	Process Incharge
5.	Dr. R.K. Sood	Chief Chemist
6.	Mr. M.P. Raithatha	Master Burner

Names of NCB Counterparts.

1.	Mr. T.N. Verma	Scientist
2.	Dr. S.N. Yadav	Scientist

CEMENT CORPORATION OF INDIA (CCI) LTD
NAYAGAON PLANT
(MANDSAUR)

CCI - Nayagaon plant is located at Mandsaur state, was started in 1980, and is producing clinker by using the suspension preheater system supplied by F.L.S. The plant is designed for a capacity of 1,200 mtpd, but 1,000 - 1,100 has been attained with a utilization factor of 83 - 91%. Expansion with a capacity of 3,000 mtpd is under construction by KCP-Fuller. All the gathered information during the visit is attached herewith.

There is a preblending system, and its reclaimer is not working and is usually down due to maintenance of its equipment, which is not working properly. The raw materials are ground in a closed circuit ball mill and the product is blended in two blending silos, where one of them is not working due to the air slide. The rotary kiln has a diameter of 4.30 m (without bricks) x 64 m in length, designed to produce 1,200 mtpd, which cannot be achieved due to different operational problems. The fuel consumption is considered high and is in the range of 900 to 910 kcal/kg. Flame shape was not evaluated clearly as the kiln was down for relining the bricks.

Plant Problems: There are no problems directly associated with the raw materials, such as build-up, coating, rings, etc. All the problems that are encountered with this plant are considered mainly operational, maintenance (mechanical and electrical) and low-efficient equipment. Some of these problems are associated with:

1. Preblending system
2. Blending system
3. Poor kiln control (high leakage air from both sides, O_2 instrument is not working, etc).
4. Spray tower is working unsatisfactorily--too much dust and heat are lost.
5. Cooler, drag chain causes operational problems. Clinker exit cooler has high temperatures.
6. Electrical power supply is not continuous.

Problems Associated with Raw Materials and Kiln Feed: The limestone deposits are very marginal and heterogenous in quality and it is necessary to add sweetener to it where its supply is not consistent. Selective quarrying of the raw materials is approached in some cases of the limestone deposits, due to low quality. Nonconsistent raw materials supply (quantity and quality) is encountered on a regular basis, that causes an erratic raw materials supply, in addition to the preblending system which is working unsatisfactorily.

One of the two blending silos is not working due to mechanical defects that will result in feeding the kiln with variable and heterogenous feed. This causes unsuitability of the kiln coating, variable clinker and cement quality, in addition to high fuel consumption due to poor control of the kiln, high leakage air and interrupted power supply.

Problems Associated with Coal: High ash content, low in content volatile matters with variable quality provided with no preblending for the coal.

Chemistry of the Kiln Feed and Clinker: Besides the heterogenous kiln feed and the variation of the $CaCO_3$ in 24 hours, the kiln feed is characterized by:

- Low A.M., H.M., L.S.F. and C/S ratio surprisingly, the C_3S/C_2S is less than 1 and the liquid phase is in a good percentage, according to the theoretical calculations.

Recommendations:

1. Although the plant is not suffering any problems from the chemistry of the raw materials, it is recommended to adjust the raw mix in order that the produced clinker will be within the following parameters:

A.M.	1.3 - 1.6
H.M.	2.1
L.S.F.	94 - 96%
C/S	3.15
C_3S	55 - 60
C_2S	20 - 25

2. Continuous supply of high grade of lime and other raw materials including coal.
3. Consistent quality of kiln feed, considering the dust added to be blended in the blending silo with the mill product, if it has no side effect.
4. Complete maintenance and cleaning of the plant and all the equipment. Put all the equipment in satisfactory operation, with sufficient supply of spare parts to avoid kiln stoppage and reduce fuel consumption to approximately 830 kcal/kg clinker.
5. Continuous electrical supply to the plant.
6. Coal should be blended and a supply of 10 - 15 days should be available. Characterize the coal before feeding it to the kiln and adjust the kiln feed accordingly.

7. Particle size of kiln feed and coal should be adjusted to the optimum. These can save an appreciable amount of energy.
8. Determination of minor constituents on a regular basis for raw materials, kiln feed, clinker and coal ash.
9. Avoid flame impingement.
10. A good process control to be established in the plant and use of X-ray spectroscopy for controlling the raw meal and kiln feed.
11. Improve the quality control of the plant and pay much attention to the maintenance of the equipment.
12. It is highly recommended to study the clinker by microscope techniques, to evaluate the crystals' shapes, size, burning and cooling processes and relate these to the cement properties. Optimum quality and operation can be obtained by this study.
13. The power consumption is 147 kwh/t of cement which is considered very high, therefore it is highly recommended to have an energy audit through all the different departments of the plant with the objective of reducing this value to the normal figure which is approximately 115 kwh/t.
14. Check all the leakage air points and stop this leakage air. Provide the kiln with efficient sealings (inlet and outlet) and a highly efficient control system.
15. Dust emission is very high throughout the plant, it is recommended to study effectively the different approaches for dust reduction.
16. Free Si varies from 6 - 9% of the kiln feed which is a very wide range and can cause quite a variation in the kiln operation and clinker quality. It is recommended to determine the percent of free Si which can be tolerated in the kiln by carrying out burnability tests.

CCI - NAYAGAON CEMENT PLANT

Information Collected

Raw Materials: Limestone and laterite. The limestone has a strength of 384 - 536 kg/cm^2, moisture 2 - 3%, free SiO_2 (quartz) 8.0 - 9.0% and with a 9 - 11.5 B.W.I. It has 81 - 82% $CaCO_3$. High grade of limestone with 93% $CaCO_3$ is used as a correction for raw mix. It is used with 3 - 2%, added to regular limestone.

	Limestone % By Weight	Laterite % By Weight
SiO_2	11.2 - 15.5	14.0 - 18.0
Al_2O_3	1.5 - 3.5	12.0 - 14.0
Fe_2O_3	0.8 - 1.5	50.0 - 60.0
CaO	42.0 - 45.0	0.5 - 1.0
MgO	0.5 - 1.0	-
SO_3	N.D.	-
K_2O	N.D.	-
Na_2O	N.D.	-
L.O.I.	34.5 - 36.5	11.0 - 13.5
Free SiO_2	9 - 11%	3 - 2%
Cl	N.D.	N.D.

Kiln Feed: 96.75% limestone and 3.25% laterite.

	% By Weight	Average
SiO_2	12.0 - 14.0	12.64
Al_2O_3	3.0 - 4.0	3.62
Fe_2O_3	2.8 - 3.4	3.00
CaO	42.5 - 43.0	43.09
MgO	0.6 - 1.0	0.98
SO_3	N.D.	-
K_2O	N.D.	-
Na_2O	N.D.	-
L.O.I.	34.0 - 35.0	34.86
S.M.	1.9 - 2.1	1.90
A.M.	1.07 - 1.17	1.20
H.M.	2.0 - 2.35	
L.S.F.	0.95 - 1.05	1.03
C/S	3.0 - 3.5	
Total Alkalies	0.28 - 0.50	
$CaCO_3$	76.0 - 77.0	

	% By Weight	Average
Cl	N.D.	
$MgCO_3$	1.3 - 2.2	
Total CO_3 as $CaCO_3$	$\simeq$ 79%	
Fineness	17.0 - 19.0 on 90 microns	
	2.0 - 2.5 on 212 microns	
Free SiO_2	In raw mix varies from 6 - 9% of total SiO_2 which is approximately 14%	

Clinker:

SiO_2	22.0 - 24.0	23.74
Al_2O_3	5.5 - 6.6	5.24
Fe_2O_3	4.5 - 5.5	5.00
CaO	62.5 - 63.5	62.59
MgO	0.8 - 1.2	1.20
SO_3	0.2 - 0.4	-
K_2O	-	-
Na_2O	-	-
L.O.I.	0.5 - 1.0	0.92
Total Alkalies	0.6 - 0.85	
Free lime	0.5 - 1.0 (1.5 - 2% Ø 1.5 occasionally)	
C.L.W.	1,050 - 1,30C	
S.M.	1.9 - 2.2	2.32
A.M.	1.0 - 1.2	1.05
H.M.	1.8 - 2.0	1.84
L.S.F.	0.83 - 0.86	0.82
C/S	2.7 - 2.9	2.64
C_3S	28.0 - 35.0	31.96
C_2S	40.0 - 48.0	44.04
C_3A	5.0 - 8.0	5.5
C_4AF	13.5 - 16.5	15.22
L.P.%	28.0 - 30.0	27.9

Process: A single compartment closed circuit ball mill with a capacity of 125 mtph supplied by a dryer and using the preheater exhaust gases for drying the raw materials. The limestone is crushed by a two-stage crusher (jaw and hammer) and is preblended with a stacker reclaimer designed for 10 : 1 preblending factor. The preblending system is working unsatisfactorily and usually is under maintenance. Two blending silos for blending the raw materials, of which one is effective and the other is not working. The kiln is 4.3 m (without brick) and 64 m in length to produce 1,200 tpd clinker. The utilization factor of the kiln is 83 - 91%. Heterogenous quality of coal is used by indirect firing to the kiln. It has a particle size of 15.0 - 16.0% on 170 mesh and approximately 1.0% on 72 mesh. The primary and secondary air are 20 and 80%, respectively. No bypass is provided to the plant and no problems are encountered with burning the kiln feed from build-up of point of view. Grate cooler is used for cooling the clinker.

<u>Some Operational Parameters</u>:

O_2 measurements	No records
CO inlet of ESP	0 - 0.4%
Burning temperature	1,400 - 1,500°C
Back end kiln temperature	900 - 980°C
Clinker temperature	130°C

			Material	Gas
Cyclone Temp. °C	II	:		500 - 550
	III	:	≃ 680	700 - 710
	IV	:	820 - 840	860 - 880
I.D. Fan	P	:	540 - 560 mm	
	T	:	350 - 380°C	

<u>Coal</u>:

C	:	55%
H	:	3.3%
H_2O	:	1 - 3%
Ash	:	29.5 - 35.5%
H.H.V.	:	4,700 kcal/kg
L.H.V.	:	3,600 kcal/kg

<u>Coal Ash</u>:

SiO_2	:	56.0 - 60.0
Al_2O_3	:	24.0 - 28.0
Fe_2O_3	:	2.8 - 6.0
SO_3	:	1.2 - 1.5
Others	:	4.0 - 8.0 (including CaO+ MgO)

Fuel consumption	900 - 910 kcal/kg
Ash contribution to clinker	5.5 - 6.4%
Firing system	Indirect firing, 15 - 16% residue on 170 mesh

Type of dust collector	ESP
Percentage of dust	7 - 10% (not measured)
Dust collected	ESP dust is being utilized along with raw mix. (ESP + conditioning tower dust are added to the kiln feed without blending)
Lifetime of bricks	4 - 6 months
Thickness of coating	Stable with 10 - 15 inches
Clinker grindability	32 kw/t cement (closed circuit)
Total kw/t cement	142 - 150 kw at 2,700 - 2,900 cm^2/gm for OPC

Breakdown of kw/t cement

Quarry	1.41
Primary crusher	0.69
Secondary crusher	1.97
Raw mill	36.31
Kiln	48.70
Coal mill	9.30
Cement mill	32.00
Packing house	3.70
Service	13.00
Total	147.08

Problems:

1. Low output, due to mechanical problems.
2. Choking packing house nozzles in the case of PPC.
3. Low lifetime of bricks, as 70% Al bricks are used.
4. Clinker quality fluctuates, with F.L. from 1.5 - 2%.
5. Reclaimer is working unsatisfactorily due to maintenance and equipment not working properly.
6. Coal is variable, with ash approximately 30%.
7. Clinker temperature at the cooler exit is $\simeq$ 125°C.

CCI NAYAGAON CEMENT PLANT
NAYAGAON DIST MANDSAUR
(M.P.)

Names of persons who participated in discussion from CCI - Nayagaon.

1.	Mr. S. K. Saigal	General Manager
2.	Mr. T. Pandey	Master Burner
3.	Mr. A. Sinha	Dy. Prodn. Manager
4.	Mr. Mishra	Ch. Engr.

Names of NCB Counterparts.

1.	Mr. A. Pahuja	Scientist
2.	Dr. V. K. Mathur	Scientist

LAKSHMI CEMENT PLANT
BANAS (RAJASTHAN)

Lakshmi Cement Plant is located at Jaykaypuram (Banas) Rajasthan at 374 m above sea level. The plant is producing clinker by dry process using the suspension preheater, provided by ACC-Babcock Limited (ABL) India. The plant is designed with one kiln to produce 500,000 mt/y, without bypass. The utilization factor of the kiln was 79 and 85% for 1984 and 1985 respectively.

The raw materials deposit (high and low limestone) is 3 km from the plant. It is heterogenous and selecting the required materials is achieved to some extent. Veins of quartz and sandstone are contaminated with the deposits, which in most cases are disregarded. The plant uses a preblending system which is inefficiently working. Grinding the raw materials and clinker is done by ball mills. The cyclones, kiln and grate cooler are oversized, with the provision of doubling the capacity by installing a second tower and a precalciner. Coal is 30% ash and is considered low in sulphur content. Clinker is cooled by a grate cooler where the temperature ranges from 60 - 70°C, exit the cooler.

Plant Operational Problems: Several problems are encountered with the operation of the plant, these are:

1. Jamming cyclone III
2. Instability of kiln operation and its coating
3. Ball formation
4. High free lime in the clinker and high expansion in cement; sometimes
5. High fuel consumption for the clinker
6. Big size of clinker ball

Some other problems are: the variation in $CaCO_3$ content of the raw materials coming from the quarry; variable feed rate; old clinker is hard to grind; etc.

Preheater and Kiln Operation: Degree of calcination in the preheater is about 36%. Cyclone III has a height of 6 m and jamming takes place at the lower end of the cyclone. The temperature profile and draft of the different cyclones and I.D. fan are within the following range.

	Temperature, °C		
	Gas	Material	Draft, mm
Cyclone I	330 ± 14	-	425
II	540 ± 19	525 ± 16	330
III	670 ± 20	655 ± 27	310-Outlet mat.
			285-Inlet gas
IV	825 ± 40	810 ± 10	175-Outlet mat.
			170-Inlet gas
I.D. Fan	280 ± 15	-	600

The jammed material is loose soft powder with few nodulus that can easily be broken. The coal that was recently used is considered of high quality from S content point.

It has been noticed that the secondary air and the back-end temperatures (850 - 900°C and 860 - 920°C respectively) are on the lower side. There is no measurement of primary air, but it is estimated to be 20%. The O_2 content instrument at [illegible]-end is not working, but this value ranges from 1 - 2% (Orsat results). There is too much leakage of air at kiln inlet and outlet. CO at kiln back-end ranges from 0.1 - 0.4%. There is no build-up at the kiln back-end and the cyclones are not provided with cleaning provisions.

Cyclone III Jamming: Unfortunately, there are no complete records on raw meal, kiln feed, dust, materials from different cyclones, jamming materials and coal with regard to Cl content, SO_3 and total alkalies. The available information from Lakshmi Cement Plant is only SO_3 for kiln feed, clinker and S for coal (both not on a regular basis) and Cl content only for samples of 23-10-86. This information is:

Sample	Cl %	SO_3%
Kiln feed	0.008	
Limestone, low grade	0.038	
Limestone, high grade	0.019	
Mix of limestone	0.024	
Cyclone III*	0.071 - 0.086	0.60 - 0.79
-do- (8.20/9.20 a.m. on 24-10-86)		0.49 - 1.15

* At different times from 10.30 a.m. - 13.30 p.m. on 23-10-86.

The previous records showed the following data:

SO_3%		S%	
Kiln Feed	Clinker	Coal	Remarks
0.19	0.66	0.35	Jamming
0.123	0.686	0.58	Jamming
0.116	0.480	0.56	Jamming
0.123	0.750	0.93	No Jamming
0.085	0.970	0.99	No Jamming

Water with different qualities is added to crushed limestone on the belt conveyor to reduce the dust during stacking the limestone. It is also used in the conditioning tower. These waters have different percentage of Cl (40.51 and 172.165 mg/litre) which can contribute to increase of Cl content in the kiln feed. However, on 24-10-1986 the Cl content of the kiln feed was in the range of 0.015% which cannot contribute to Cl problem.

Other data were collected during our visit and are as follows:

	SO_3%
Cyclone III - wall material (22-10-86)	0.80
Cyclone III - Coarse materials near door (22-10-86)	0.34
Cyclone III - Jammed material (22-10-86)	0.62
Cyclone III - Nodulus (22-10-86)	0.90
Kiln feed - (22-10-86)	0.15
Raw meal - (22-10-86)	0.14
Raw meal - (17-10-86)	0.20

It was noticed that when SO_3 is low in cyclone III, jamming occurs, but if it reaches to more than 1, no jamming occurs, according to the plant personnel.

Reasons for Jamming Cyclone III: At this stage, no exact picture and measurements can be concluded to stop cyclone III jamming as long as analysis of Cl, SO_3, Na_2O and K_2O for raw meal, kiln feed, dust, materials from cyclones, jammed materials and coal are not available. Build-up in preheater system can be attributed to unbalanced sulphur/alkali ratio, if there is no operational problem(s).

When new materials and fuel contain an equal quantity of sulfur and alkali (calculated on a mol. basis with certain adjustments for relative volatility of Na_2O, K_2O and SO_3), the sulfur/alkali ratio is theoretically balanced. When the sulfur/alkali ratio (S/K) is not in balance because of excessive amounts of sulfur present in the raw materials and/or fuel, the sulfur will preferentially combine with all available alkalies, and the alkali sulfates will condense primarily in the rotary kiln. The excess of sulfur combines with CaO to form calcium sulfate and frequently potassium calcium sulfate which condense as a liquid at lower temperatures. As S/K ratio increases, the increased quantities of S in the form of $CaSO_4$ contribute to partial pressure conditions resulting in reducing the condensation temperature for $CaSO_4$ and intermediate compounds. The condensates increase a build-up of sticky materials including process dust that is agglomerated with the sticky mass.

When insufficient sulfur is available in the SP system, the excess alkalies will form other compounds that also condense at the feed end of the rotary kiln and at lower portions of the SP system. It seems that Lakshmi Cement is suffering from insufficient sulfur (too little S) in raw mix and fuel, if there is no other operational problem(s). A substantial S/K imbalance exists due to the inherent deficiencies of S. Therefore, in this case (until a detailed chemical analysis for the minor oxides and Cl can be obtained) it is recommended to change to higher side of the S in the fuel, if it is not possible in the raw materials. It is worth mentioning that greater amounts of build-up can be eliminated by manual or automated removal of build-up deposit. Access must be supplied to the points where jamming occurs so that they can be removed regularly.

Recommendations:

1. Tentatively until the analysis of Cl, SO_3, alkalies for the materials described above, use high S - coal or add some amount of gypsum to the raw material to increases SO_3 content and reach the balance of S/K. Using dust with kiln feed must be constant.
2. Supply an automatic cleaning system for cyclone III.
3. Check and stop all the leakage points through all the pyroprocessing system.
4. Increase the temperature profile in all the pyroprocessing system to reach the following parameters.
   - Kiln exit gas temperature 1,050 - 1,100°C
   - Preheater exit gas temperature ≃ 360°C
   - Stage 4 exit gas temperature ≃ 850°C
   - Decrease the primary air and increase the secondary air (quantitative and qualitative)
     - Adjust the clinker cooler and the flame shape

   These will help in increasing the temperature of cyclone III and change the T-profile of all the system.

5. Oxygen gas analyzer at the back end of the kiln should be repaired to measure the oxygen regularly and to be kept at about 2 - 3%.
6. Kiln is large in size and small clinker bed is usually sintered in the kiln. This can produce an overburned clinker. In this respect the clinker bed should be increased which may be required also to increase the kiln speed.
7. Selective quarrying is highly recommended with provision not to use quartz and/or silicious materials, to keep the free silica low in the kiln feed.
8. Perform burnability and volatility tests on different mix designs and with different particle size (considering the ash contribution) to obtain the optimum mix components. Effect of free silica should be studied.
9. The presently used kiln feed is considered unbalanced. It is recommended to adjust the kiln feed in order that the produced clinker (with the coal ash contribution) to be within the following range:

   S.M. : 2.2 - 2.4 (by using argillaceous materials not high in free SiO_2 and/or Al_2O_3).

   A.M. : 1.4 - 1.6 (increase Fe_2O_3 and decrease Al_2O_3)

   L.P. : $\simeq$ 28%

   C_3S/C_2S : $\simeq$ 2.5

10. Feed the kiln with consistent CaO content and residue on 170 and 72 mesh. In this respect using X-ray diffractometer is recommended to determine the CaO content. Feed should be homogenized well.
11. Dust, in the case of its use, should be blended with the mill product in the blended silo. No dust will be allowed to feed the kiln without blending. Dust handling should be engineered carefully.
12. Coal should be blended and a continuous supply for future days should be available (as it is observed). Coal should be characterized before feeding it to the kiln and the kiln feed adjusted accordingly. Coal with ash less than 30% and with high S - content is highly recommended (if jamming is due to deficiency of S). Particle size of coal to kiln should be adjusted to the optimum.
13. It is very important and essential to determine minor constituents for all the materials, including coal and coal ash (Cl is not necessary in this case). The laboratory personnel should be trained to perform these tests regularly and accurately.
14. Flame shape required to be adjusted using adequate coal fineness, the correct amount of primary air and avoid flame impingement.
15. It is required to have a good process control utilizing X-ray diffractometer.

16. Improve the quality control and sampling procedure.
17. Dust from different collecting points should be completely analyzed for alkalies, carbonates, SO_3, Cl, etc. Its quantity should be determined.
18. It is highly recommended to study the clinker by microscope techniques, evaluate the crystals' shapes, sizes, burning and cooling processes and relate these to the cement properties. Optimum quality and operation can be obtained by this study.
19. The power consumption per ton of OPC cement is considered relatively high (about 130 kwh/t). It is recommended to have an energy audit through all the plant to study possibilities of saving energy at different points.
20. Reduce the fineness of the kiln feed to about 14% on 170 mesh. In this respect, it is forseen to increase S.M. and reduce the L.P. to prevent balling of the clinker and hard grind clinker in the cement mill.
21. It is recommended to convert the cement mill to internal water cooling. This will help in increasing the mill efficiency and decrease the cement expansion. Thirty-five kw/t of OPC cement in an open circuit at cm^2/g is considered high, this can be attributed to high liquid phase.
22. Carry out a feasibility study to convert the existing kiln from SP system to precalciner (PC), as long as it is designed for PC Process.

<u>Other Subjects Discussed</u>:

1. Raw mix, limestone quality, ideal raw mix, corrective materials.
2. Quarry variation, Si-content in raw mix, minor constituents, stacking system, high grade limestone.
3. Raw mill output, ball charge, raw mill operation, hoppers jamming, diaphragm choking and slot opening, raw mill separator.
4. Rotary kiln and clinker production, clinker composition, clinker size, clinker grindability and effect of liquid phase, leakage air in the kiln.
5. Coal quality, consumption and coal blending.
6. Cement mill output, cement color and quality, water spray (external and internal), mill charge.
7. Total power consumption.

LAKSHMI CEMENT PLANT

Information Collected

Raw Materials: Limestone which has a chemical composition similar to a raw mix is used. The same deposit has high and low content of $CaCO_3$ and both are usually quarried from the quarry which is about 3 km from the plant. No information is available on the raw materials properties except that it has 0.2 - 1.0% moisture, average 77.5% $CaCO_3$ (approximately), and a Bond Work index of 9.5 kwh/t.

Chemical Analysis

(% By Weight)

	Min.	Max.	Average
SiO_2	11.16	12.26	11.65
Al_2O_3	3.64	4.22	4.00
Fe_2O_3	2.10	2.50	2.31
CaO	44.08	45.34	44.54
MgO	0.68	1.14	1.00
SO_3	0.02	0.24	0.15
K_2O	N.D.	N.D.	N.D.
Na_2O	N.D.	N.D.	N.D.
L.O.I.	35.14	36.39	35.64
Total	96.82	102.09	99.29
Free SiO_2	------------------N.D. (but ranges from 6-8%)		
Cl	------------------N.D.--------------		
$CaCO_3$			$\simeq$ 75.18
$MgCO_3$			2.12 - 2.5
S.M.			1.84
A.M.			1.73
L.S.F.			1.14

Kiln Feed: The average shown above is considered the kiln feed analysis. It has a fineness of 16 - 18% on 170 mesh, (sometimes reaches 20%) and 2.5 - 3.0% on 72 mesh.

Clinker Analysis:

	Range	Average
SiO_2	20.1 - 22.0	20.90
Al_2O_3	6.34 - 7.42	6.95
Fe_2O_3	3.30 - 3.80	3.50
CaO	64.08 - 65.6	64.58
MgO	1.8 - 2.26	2.08
SO_3	N.D.	N.D.
K_2O	N.D.	N.D.
Na_2O	N.D.	N.D.
L.O.I.		0.57
Total		98.66
F.L.		2.12 - 2.5%
C.L.W.		1,250 - 1,300
S.M.		2.0
A.M.		1.98
H.M.		2.06
L.S.F.		0.91
C/S		3.08
C_3S		41.5
C_2S		29.08
C_3A		12.50
C_4AF		10.64
LP		31.2%

Process: The limestone deposits are variable where 15 - 20% clay is mixed with the limestone and in some places the clay varies from 60 - 40%. Quartz and siliceous materials are mixed as inclusion with limestone. The quarry is operated with some degree of selective the raw materials, which are Hazemag crushed in the Hazemag crusher. The plant has a preblending system for the raw materials that is poorly designed and inefficient. Water is added to the crushed limestone to decrease the dust during the stacking process. The ball mill is a closed circuit with two compartments and a capacity of 130 mtph and has three bins mtph (high and low limestone grades and additive). Normally one bin is used. There are two blending silos with a blending efficiency of 5 : 1. The kiln system is a preheater system (single tower) with an effective diameter of 4.2 x 68 m, designed to produce 500,000 mtpy, which has not been achieved. It is an oversize system, with a provision for a second tower and a precalciner to produce about 3,000 mtpd clinker. The present fuel consumption is approximately 900 kcal/kg clinker. The utilization factor of the kiln ranged from 80 to 85% for the last two years. The cement mill is an open circuit with three compartments. Grate cooler is used for cooling the clinker and it is oversized in capacity. It is designed to produce 3,000 mtpd.

Operational Parameters:

CO back end kiln	0.1 - 0.4%	
O_2 back end kiln	Not working	
O_2 - near I.D. fan	6%	
Burning temperature	1,300 - 1,350°C	
Back end temperature	860 - 920°C	
Clinker temperature, cooler exit	62 - 70°C	
Spray tower temperature	290°C - in	
	145 - 150°C-out	
I.D. fan temperature	290 - 320°C	
	Temp°C	P (mm WG)
Cyclone I	≃ 350	400
II	≃ 530	300 - 280
III	≃ 690	260 - 280
IV	≃ 810	150 - 180
Primary air, %	≃ 20	
Secondary air temperature	850 - 900°C	

Coal: Only following data is available.

H_2O	2.28%
Ash	29.5%
U.H.V.	4509 kcal/kg (average)

Coal Ash:

SiO_2	58.00%
Al_2O_3	24.48%
Fe_2O_3	9.30%
CaO	6.17%
Others	Undetermined

Fuel Consumption: 900 - 950 kcal/kg

Ash Contribution to Clinker: 5 - 6%

Firing System: Indirect firing, with 13 - 15% residue on 170 mesh.

Type of Dust Collector: ESP

% of Dust: Not measured

Dust Collected: Mill working in the circuit back to raw mill and kiln feed elevator. Mill down to the kiln feed directly. Dust from spray tower is going to the kiln feed. No analysis of dust is available.

Lifetime of Bricks: $\simeq$6 Months

Thickness of Coating: 16 - 18 inches. Stable in burning zone. Unstable in Preburning zone.

Clinker Grindability: $\simeq$35 kw/t cement (open circuit)

Total kw/t Cement: 125 - 130 at 2,800 cm^2/gm for OPC.

Breakdown of kw/t Cement:

Crusher	2.50 kwh/t of limestone
Raw mill	24.50 kwh/t of raw meal
Kiln	50.00 kwh/t of clinker
Cement mill	35.00 kwh/t of cement
Packing	3.50 kwh/t of cement
Total	115.5

This corresponds to approximately 130 kwh/t of cement.

Problems:

1. Free lime is higher
2. Cyclone III jamming

LAKSHMI CEMENT LIMITED
JAYKAYPURAM DIST SIROHI, BANAS

Names of the persons who participated in discussion from Lakshmi Cement.

1.	Mr. S. S. Jain	Vice President
2.	Mr. O. N. Rai	General Manager (Works)
3.	Mr. S. S. Khandekar	Manager (Engg.)
4.	Mr. B. S. Dulani	Prodn. Manager
5.	Mr. S. Barnah	Mines Manager
6.	Mr. V. Koteshwaraiah	Master Burner
7.	Mr. B.K. Jagetia	Dy. Chief Chemist

Names of NCB Counterparts.

1.	Mr. A. Pahuja	Scientist
2.	Dr. V.K. Mathur	Scientist

SHREE CEMENT LIMITED
BEAWAR - AJMER
(RAJASTHAN)

Shree Cement Limited is located at Beawar, Ajmer of Rajasthan State. The plant is producing clinker by dry process using the precalciner technique and F.L.S. System. The kiln is designed to produce 1,800 mtpd, but 2,500 mtpd can be obtained. The utilization factor of the kiln is 100%. The plant is without by-pass and no problems are encountered with jamming or build-up in the cyclone. All the gathered information follows this report.

There is a preblending system for blending the crushed raw materials, but its stacker is working inefficiently. The blending silo of the ground raw meal is usually at 40% efficiency. The raw materials are ground in a roller mill and the kiln feed has a fineness of 14 - 16% on 170 mesh and 1.0 - 1.5% on 72 mesh. The rotary kiln has a dimension of 3.55 m in diameter (inside brick) and 56 m length. Indirect coal firing is used for sintering the raw materials.

Plant Operational Problems: Practically, it can be said that there are no problems from the raw materials point with regard to cyclone build-up and/or ring formations in the kiln. The plant is in a good condition with an excellent kiln production. Some problems are associated with the raw materials (heterogenity, high free SiO_2, low SiO_2 content) and with the clinker (high free lime). Some other operational problems are encountered with the plant such as: inefficient preblending and blending systems; unavailability of water for cooling the gases which increase the amount of the dust in the stack gas; blocking the discharge diaphragm of the cement mill; variable coal quality and its ash content.

Causes of High Free Lime in the Clinker. High free lime in the produced clinker can be attributed to one or more of the following factors:

1. Coarse kiln feed
2. Poor blended feed
3. Variable percentage of $CaCO_3$ of the kiln feed
4. High percentage of free SiO_2
5. Improper sintering process and instability of kiln operation

Therefore, it is recommended to decrease the kiln feed to about 12% residue on 170 mesh and 1.5% on 72 mesh, and increase the efficiency of the blending factor so that the kiln feed (included that the dust should be blended with the raw meal) is within a range of ±0.2 $CaCO_3$ (it is preferable to adjust the target of the kiln feed by CaO and not by $CaCO_3$). It is recommended also to perform burnability test on different mixes with different composition, free SiO_2 and fineness to determine the characteristic of the optimum mix, hence the properties of the clinker to fall within the standard known properties. It is also recommended not to use quartz or free SiO_2 in the mix, but it is preferable to use soluble SiO_2 which is found in argillaceous materials.

Recommendations:

1. It is highly recommended to adjust the kiln feed so that the produced clinker after considering the ash contribution should be within the following limits:

S.M.	2.3 - 2.5
A.M.	1.3 - 1.6
L.S.F.	92 - 95%
CaO/SiO_2	3.15
C_3S	52 - 55
C_2S	20 - 25
L.P.	$\simeq$28%
C_3S/C_2S	$\simeq$2.3

It is required therefore an effective quarry selective of raw materials which may increase the waste. If such a clinker is obtained and is well burned, the free lime and the expansion will be definitely low. The production of the cement mill will also be improved.

2. The kiln feed should be consistent chemically and in its fineness, taking into consideration the dust added, which should be carefully handled and blended.
3. Coal should be blended and a supply for 10 - 15 days should be available. Characterize the coal before feeding it to the kiln and/or precalciner and adjust the kiln feed accordingly. Coal with ash content less than 30% is highly recommended.
4. Particle size of the kiln feed and the coal should be adjusted to the optimum.
5. Determination of minor constituents are requested for raw materials, coal, ash, dust, whenever it is applied.
6. Avoid flame impingement.
7. It is highly recommended to study the clinker by microscope techniques, evaluate the crystals' shapes, sizes, burning and cooling processes and relate these to the cement properties. Optimum quality and operation can be obtained by this study.

8. To have an energy audit for the power consumption through all the plant with the possibilities ‹ = energy saving at different points.
9. Concentrate on selecting the raw materials from the quarry. In this respect an effective computer program will be very beneficial and more productive.

Other Subjects Discussed:

1. Burning rice husk ash in the precalciner.
2. Blocking the discharge diaphragm of the cement mill, clinker temperature, drying the pozzolanic materials, mill charge and ball distribution.

SHREE CEMENT LIMITED
BEAWAR RAJASTHAN

Information Collected

Raw Materials: The raw material deposits are 2 - 3 km from the plant and are heterogenous. Three bands of limestone can be identified.

Band A	77 - 80% $CaCO_3$,
Band B	70 - 74% $CaCO_3$ and
Band C	70 - 79% $CaCO_3$

Calcareous clay and mica shist are found between the three bands. Clay pockets are contaminated with band C, which affects the quality supplied. The quarry is operated by selecting mining and for each one ton of limestone, about 0.81 ton of poor quality is quarried and wasted. Free SiO_2 with about 3 - 8% is found in the limestone, as quartz is found as interstitial material. The limestone is crushed by the gyratory crusher located in the quarry and the crushed limestone is transported to the plant by an aerial ropeway. There is a small lab in the quarry to perform the $CaCO_3$. High grade limestone is separated and stored separately as it is used as a sweetener. Laterite is used as an iron additive. The chemical analysis of raw materials are as follows:

	Limestone			
	High Grade	Feedable	Low Grade	Laterite
SiO_2	4.54	11.00	19.12	21.54
Al_2O_3	1.78	3.56	6.82	9.10
Fe_2O_3	1.30	2.00	3.60	56.40
CaO	48.00	43.20	35.60	1.20
MgO	3.00	2.01	2.31	0.60
SO_3	-	-	-	-
K_2O	-	0.68	0.82	-
Na_2O	-	0.28	0.51	-
L.O.I.	41.19	35.98	24.12	-
Moisture	-	6.00	8.00	7.00

There is a preblending for the limestone with a present blending factor 5.6 : 1 as the stacker is working inefficiently.

Kiln Feed: Ratio ... feedable + 1% laterite.

	% By Weight		
SiO_2	11.64		
Al_2O_3	4.02		
Fe_2O_3	2.10		
CaO	43.19	S.M.	1.90
MgO	1.93	A.M.	1.91
SO_3	-	H.M.	2.43
K_2O	0.68	L.S.F.	1.11
Na_2O	0.28		
L.O.I.	35.35		
Total	99.19		
$CaCO_3$	$\simeq$ 76.90		
$MgCO_3$	1.68		
Cl	0.005		
Fineness	14 - 16% on 170 and 1.6 on 72 mesh		
Free Silica	Reaches about 5 - 8%		

Clinker:

SiO_2	21.20	S.M.	2.08
Al_2O_3	6.90	A.M.	2.09
Fe_2O_3	3.30	H.M.	2.04
CaO	64.00	L.S.F.	0.92
MgO	2.12	C/S	3.01
SO_3	-	C_3S	38
K_2O	0.98	C_2S	32
Na_2O	0.42	C_3A	13
L.O.I.	0.50	C_4AF	10
Total	99.42	LP	31.6%
Total alkalies	1.40		
C.L.W.	1,220		
F.L.	$\simeq$1.68 - can reach up to 3%		

Process: The plant started in 1985 with a single precalciner system (F.L.S.), and is located ... 470 m above sea level. The raw materials are ground by a roller mill with a capacity of 175 t/h utilizing the preheater gases. Some problems are encountered ... roller mill regarding the bearings and linears of the ... 200 ... can be obtained. The blending silos are working inefficie... They are guaranteed for 10 : 1, but the present blending factor is 6 : 1. The calcination in the PC is 85 - 90% with split of fuel of 60-65 : 40-35 in PC : kiln. Coal with approximately 22% residue on 170 mesh is used for PC, while for kiln coal with 16% residue on 170 mesh is utilized. Rotary kiln is 3.35 m in diameter (inside brick) x 56 m length, designed to produce 1,800 mtpd, but 2,500 mtpd and more can be achieved. There is no problem of build-up or jamming in the cyclones. Indirect coal firing is used and there is no blending system for coal, but hand blending is provided in some cases. The burner pipe is motorized for moving within a distance of two meters. Cement mill is an open circuit with two compartments (33 : 28% filling percentage, respectively). Production of cement mill is low due to the blocking of the outlet diaphragm.

Some Operational Data:

O_2 at back end of kiln		2 - 2.5%
O_2 at preheater outlet		5 - 6%
CO at PC outlet		0.01 - 0.02%
PC inlet temperature		600°C
Tertiary air temperature		750 - 800°C
Gas temperature at PC		950 - 1,000°C
Kiln inlet temperature		1,050 - 1,100°C
Preheater outlet		0 (zero) CO
Preheater outlet temperature		350 - 360°C
Percentage of primary air		16%
Secondary air temperature		850 - 900°C
Burning temperature		1,400 - 1,450°C
Gas temperature Cyclone	I	$\simeq$ 370°C
	II	$\simeq$ 540°C
	III	$\simeq$ 780°C
	IV	870 - 890°C

Coal:

C	55%
H	5.2%
N	0.89%
O	1.50%
H_2O	3.0%
Ash	29.23%
HHV	4452 kcal/kg

Coal Ash:	SiO_2	61.34%
	Al_2O_3	25.80%
	Fe_2O_3	7.20%
	SO_3	0.40%
	CaO	2.0%

Fuel Consumption: 800 kcal/kg

Particle Size of Coal Kiln : 15 - 16%, 170 mesh
0.6 - 0.8%, 72 mesh
PC : 22 - 24%, 170 mesh

Ash Contribution to Clinker: 5%

% of Dust: 7 - 8%

Type of Dust: ESP

Dust Collected: Is usable by taking it back to the silo.

Lifetime of Bricks: 6 - 8 months

Coating in the Kiln: Has a thickness of 200 - 250 mm and is stable.

kw/t Cement: OPC 110 at 3000 cm^2/gm
PPC 107 at 4000 cm^2/gm

Plant Problems: Generally, there are no problems from the point of burning the raw materials, except that:

1. High free lime in the clinker.
2. Low Si content in the clinker.

Besides there are some operational problems such as:

1. Unavailability of water for cooling the exit gases in the spray tower.
2. High coal ash.
3. Power failure.

SHREE CEMENTS LIMITED
BEAWAR RAJASTHAN

Names of persons who participated in discussion from Shree Cements Limited.

1.	Mr. N.R. Jain	General Manager (Works)
2.	Mr. B. M. Mathur	Production Manager
3.	Mr. S. N. Upadhaya	Master Burner
4.	Dr. L. B. Singh	Dy Chief Engineer
5.	Mr. C. K. Khatri	Dy Chief Chemist

Names of NCB Counterparts.

1.	Mr. A. Pahuja	Scientist
2.	Dr. V. K. Mathur	Scientist

PANYAM CEMENTS AND MINERAL INDUSTRIES LIMITED CEMENT NAGAR

Panyam Cements-Cement Nagar is located 50 km from District Has-Karnool. Clinker is produced from three kilns using suspension preheater system. The layout of the plant and the kilns is unorganized and the equipment is not parallel to each other.

The limestone quarry is 2 - 3 km from the plant, where a double hammer crusher (150 mtph) is located. The crushed limestone is transported to the plant site by a bi-cable ropeway. Three different layers of limestone with thickness of about 32 meters are removed to obtain approximately 24 meters of useable limestone. It can be said approximately two tons of quartz, shale, and low-grade limestone are wasted to obtain one ton of high and medium grade limestone.

No geological studies and core drilling were done on the limestone when the plant started, except surface samples from the outcrops. In 1984, ACC did geological and core drilling studies on nearby deposits, similar to the existing deposits. In the new deposit, 0.6 t will be wasted for each one ton usable limestone. The new reserves have:

Cl	:	0.01%
SO_3	:	0.30 - 0.55%
P_2O_5	:	0.10 - 0.20%
Na_2O	:	0.08 - 0.14%
K_2O	:	0.18 - 0.31%

The limestone is suitable for the dry process with permissible limits of minor components and no alkalies problems, according to the ACC study. High grade limestone, bauxite and iron ore will be required.

The plant has several bottlenecks. Starting from the quarry, the following are the bottlenecks:

1. Limestone crushing and transport.
2. Raw materials grinding (low efficient raw mills, high power consumption, high residue).
3. High free silica in the raw mix, coupled with high residue on 170 and 72 mesh.
4. Variable composition of kiln feed and nonexistence of a blending system.
5. Inefficient sintering process through all the kilns, resulting in high fuel consumption.

6. Coal mills are under capacity, resulting in grinding the coal coarser.
7. Low and variable quality of coal with high moisture content.
8. High amount of leakage and poor process control. High fuel consumption.
9. Higher power consumption (kwh/t cement).
10. Dust, ESP, water for cooling, maintenance, etc.

However, despite all these bottlenecks and production problems, the clinker produced has 0.7 - 1.0% maximum free lime, the cement does not encounter expansion and the strength is high; as per the cement personnel. It is a credit that a plant is running with feed of variable $CaCO_3$ and high residue, variable coal and high residue, and high free SiO_2, etc., and obtaining a good quality of cement.

Recommendations:

1. The plant has many bottlenecks, production and operational problems. In this respect, it is highly recommended to balance the plant with the material starting from the quarry, crusher, ropeway, operating hours, raw mills capacity, etc.
2. The kiln should be fed with continuous constant and homogenized feed all the time. $CaCO_3$ to be kept ± 0.2% for steady and stable kiln operation and homogeneous quality.
3. According to the data received from Panyam Cement, (which is followed after these recommendations), the clinker produced is considered of good quality and with low percentage of free lime, although the kiln feed has about 80% of free SiO_2 of the total which is 12%. It seems, from this information, that there are no problems for burning such a raw mix which is characterized with high fineness 19 - 23% on 170 mesh and 3 - 4.8% on 72 mesh. It is recommended to keep the produced clinker at approximately 2.10 H.M. and L.S.F. between 92 - 95%. C_3S should be around 52 while C_2S around 25 and the liquid phase in the range of 28%. S.M. in the range of 2.2 and A.M. of 1.2 are considered good figures, as long as the plant is running with these values for a high free silica.
4. Dust collected from kilns, in the case of its use, should be blended and homogenized well with the mill product. Dust handling should be engineered carefully.
5. Coal with 30% ash content maximum and capable of producing temperature about 1,450°C, is recommended to be used. Coal stock for 10 - 15 days should be provided and a blending system must be forseen. Characterize the coal before firing and adjust the kiln feed accordingly.
6. Particle size of the coal to the kiln should be adjusted to the optimum.
7. Determination of minor constituents for raw meal, kiln feed, dust, coal and coal ash on a regular basis should be considered.

8. Flame shape required to be adjusted using adequate coal fineness and primary air. Avoid flame impingement.
9. Temperature of secondary air and kiln inlet chamber (800 and 900°C respectively) are considered low. These should be increased.
10. Good blending of the kiln feed is essential as well as a weight-feeder to the raw mills. Consideration of this equipment is recommended.
11. Establish a good process control and use X-ray spectroscopy for the analysis. Determination of CaO content for the kiln feed rather than $CaCO_3$ is advisable.
12. Perform burnability test on diffeent mixes with different particle size and free silica content, and study the effect of coal ash (different percentage) on the clinker quality and burnability to obtain the optimum raw mix constituents. High amount of free SiO_2 cannot be tolerated in rotary kiln to obtain high quality of clinker. Establish a system to remove the quartz from the crushed limestone.
13. Plant requires complete engineering check-up, rehabilitation, instrumentation adjustment. Material and heat balances, and raw mills design and their ball charges should be checked to reduce the high kwh/t of raw meal grinding.
14. Greater attention should be paid to maintenance of the plant and quality control.
15. It is highly recommended to study the clinker by microscope techniques, evaluate the crystals' shapes, sizes, burning and cooling process and relate these to the cement properties. Optimum quality and operation can be obtained by this study.
16. The fuel and power consumptions (1,050 - 1,150 kcal/kg clinker and 175 kwh/t cement) are very high. The pyroprocessing system should be checked and stop any leakage, using low percent of primary air, high temperature of secondary air, dry coal with optimum size, adjustable and balanced raw mix with easy burning characteristics. It is highly recommended to have an energy audit for all the plant and especially for the grinding mills. It seems that utilizing a vertical mill is an energy saver for raw material grinding. In this case, consideration for free SiO_2 should not be overlooked.

PANYAM CEMENT AND MINERAL INDUSTRIES LTD
CEMENTNAGAR (50 km FROM DISTRICT KURNOOL)

Information Collected

Raw Materials:

1. Limestone: Hard, dense, fine grained with 4 - 5 hardness on Moh's scale and 0.1 - 0.5% moisture. It is considered a siliceous limestone as it contains about 13% SiO_2.
2. High grade limestone, which is used as a sweetener, with about 52% CaO. Sweetener is used only occasionally and in the rainy season, sweetener cannot be handled. Basides, bauxite and iron ore are used as correctives.

% By Weight

	Limestone	Bauxite	Iron Ore	Limestone High Grade
SiO_2	13.22	9.88	11.92	3.75
Al_2O_3	1.25	44.60	-	1.14
Fe_2O_3	1.20	20.20	79.90	0.48
CaO	46.02	0.20	-	52.57
MgO	1.07	Trace	-	0.64
SO_3	0.15	-	-	-
K_2O Na_2O	0.40	-	-	-
L.O.I.	36.64	22.10	5.20	40.86
Total	99.95	99.88*	97.02	99.44
Free SiO_2	10.80	-	-	-
Cl	0.006	-	-	-
Total Alkalies	0.3 - 0.5	-	-	-
TiO_2	-	3.01	-	-

* Includes 3.01% TiO_2

Kiln Feed: With percentage: 85 : 4 : 1 : 10 - limestone : bauxite : iron ore : sweetener, respectively.

	% By Weight	
SiO_2	12.00	
Al_2O_3	2.66	
$F3_2O_3$	2.24	S.M. : 2.45
CaO	45.08	A.M. : 1.19
MgO	1.07	H.M. : 2.67
SO_3	0.15	L.S.E. : 117.86%
K_2O	0.30	
Ne_2O		
L.O.I.	35.95	
Total	99.45	
Free SiO_2	≃ 80% of total SiO_2	
$CaCO_3$	79.50 - 80.50%	
$MgCO_3$	1.50 - 2.00%	
Cl	0.006%	

Fineness : 19 - 23 on 170 mesh and 3 - 4.8% on 72 mesh.

Clinker:

		*
SiO_2	22.75	
Al_2O_3	5.17	S.M. : 2.29
Fe_2O_3	4.60	A.M. : 1.12
CaO	64.02	H.M. : 1.63
MgO	1.25	L.S.I. : 90%
SO_3	N.D.	C_3S : 48.3
K_2O)	0.50	C_2S : 27.1
Na_2O)		C_3A : 5.9
L.O.I.	-	C_4AF : 14.00
Total	98.29	(*Some of these values do not agree with the given clinker analysis)
F.L.	0.8 - 1.0%	
C.L.W.	1,050 - 1,250	

Process: The plant has three units working now by dry process using the suspension preheater system, which were set up at different times. Kilns 1 and 2 were started in 1958 and 1963, respectively, and were converted to dry process in 1978 and 1974, respectively. Kiln 2 of wet process was cut into two. One piece of shell reinstalled as dry process of kiln 2 in 1974. The other piece with original planetary cooler was installed as dry process of kiln 1 in 1978. The chain in planetary cooler was placed by lifter in 1985. 1,330 - 1,400°C is considered the best burning temperature, can be obtained.

Kiln 3 was installed in 1965 with dry process. The designed capacities are 400, 550 and 600 mptd for kilns 1, 2, and 3, respectively. The capacities of kilns 1 and 2 have not been obtained, as 350 and 480 mtpd are the maximum production. Utilization factors are 87.5, 81.3 and 103% for each kiln, respectively. Several suppliers provided the different equipment of the plant and the layout of the equipment is not parallel and not up to modern technology. There are several bottlenecks through all the production process, starting from the crusher, which results in variable clinker quality. The present production of the open-circuit ball raw mills (3) are not sufficient for the kiln feeds, therefore the mill product is kept to a fineness 14 - 23% on 170 mesh and 3 - 4.8% on 72 mesh. Besides this high fineness, variable kiln feed (within ±1% $CaCO_3$ and sometimes 2%, due to poor blending system) and variable coal (about 35 - 40% ash), the plant personnel claimed that the free lime in the produced clinker varies only from 0.8 - 1.0%. The strength of the produced cement is 200 - 230, 300 - 320 and 400 - 450 kg km^2 for 3, 7, and 28 days, respectively, according to the plant personnel. The coal is poor quality with high ash content and low heating value of 3,500 kcal/kg. Sulfur is 1.00 - 2.20% for the coal. The burning temperature of the kiln feed ranges from 1,400 - 1,560°C. Kiln 3 (installed in 1968) has no blending system. Blending silos for kiln 1 and 2 are very small in capacity and ineffective. Kiln 1 has a planetary cooler while 2 and 3 have grate coolers.

<u>Some Operational Data</u>:

Primary Air	: 15 - 20%
Back end kiln temperature	: ≃900°C
Degree of calcination	: 25 - 30%
Burning zone temperature	: 1,330 - 1,400°C
Gases out of preheater	: 300 - 350°C
O_2 at I.D. fan	: ≃5.8%
O_2 at back end of kiln	: 2 - 4%

<u>Coal</u>:

C	: 42.71%
H	: 2.46%
N	: 0.92%
O	: 0.66%
S	: 1.6 - 2.5%
H_2O	: 4.5 - 6.5% sometimes 8%
Ash	: 34 - 37%
H.H.V.	: 3,800 kcal/kg
L.H.V.	: 3,500 kcal/kg

Coal Ash:		
	SiO_2	: 62.60%
	Al_2O_3	: 23.00%
	Fe_2O_3	: 3.88%
	CaO	: 3.32%
	MgO	: 1.21%
	TiO_2	: 1.34%
	P_2O_5	: 0.23%
	SO_3	: 0.30%
	Others	: 4.12%

Coal Fineness: 20 - 24% on 170 mesh

Fuel Consumption: 1,050 - 1,150 kcal/kg (26 - 28%)

Ash Contribution to Clinker: 7 - 9%

Dust Collectors: Cyclones and ESP (which is not working).

Dust Collected: Is usable and circulated in the process.

Clinker Quality: Min. 2 mm and max. 20 mm clinker with shell dark in color encapsulated core light in color is the type of clinker produced.

Raw Materials Grindability: ≃67.70 kwh/t (on basis of cement).

Clinker Grindability: 52.00 kwh/t.

kwh/t of Cement: 175 kwh/t for either OPC at 2,700 - 3,100 cm^2/gm or PPC with 3,500 - 4,000 cm^2/gm. Using open circut; distributed as follows:

Quarry	:	0.25
Ropeway	:	0.52
Clinker	:	0.98
Raw Mill	:	67.70
Kilns	:	36.98
Coal Mill	:	9.63
Cement Mill	:	51.95
Packing House	:	1.84
Crane	:	0.70
Lab + pumps	:	2.85
Light + colony	:	3.52
Total		176.92

Bottlenecks: The free silica of limestone coupled with high ash coal, added to high ash absorption are the main bottlenecks in the kiln.

- High power consumptions.

PANYAM CEMENT

CEMENT NAGAR

Names of the persons who participated in discussions from Panyam Cement.

1.	Mr. K. Vithal Rao	General Manager
2.	Mr. V. Surandra Raj	Manager (Tech.)
3.	Mr. Parma Sivachari	Deputy Manager (Tech.)
4.	Mr. Sanjeevappa	Chief Elecl. Engineer
5.	Mr. A. Sambasiva Reddy	Deputy Manager
6.	Mr. D. Rammurthy Reddy	C.S.O.
7.	Mr. G. Yella Ramaiah	Senior Mechanical Engineer
8.	Mr. G. Venkateswarlu	Packing House Incharge
9.	Mr. Sambasiva Rao	Senior Engineer Drawing
10.	Mr. Gopal Reddy	A. E. Workshops

Names of NCB Counterparts.

1.	Dr. P.B. Rao	Scientist
2.	Mr. A.D. Agnihotri	Mining Engineer

DURGA CEMENT WORKS
DURGAPURAM

Durga Cement Works at Durgapuram is located at Dachepalli, Andrha Pradesh. It is one of the cement plants which belong to the Andhra Cement Company Limited. The plant is producing clinker by dry process using 4-stage suspension preheater system. The designed capacity of the plant is 1,350 mtpd, but 1,520 was achieved. This kiln (4.35 m diameter inside shell and 66 m long) is under expansion now by adding another tower (5-stage suspension preheater and a precalciner; F.L.S. system). It is expected that the expansion will be completed within a few months. At present, the raw materials are ground in a ball mill which produces more fine, but another mill (vertical) is under installation for the expansion, which will feed the kiln together with the existing ball mill.

The raw material deposits are limestone with variable pockets, different in thickness of hard pure calcite and quartz crystals. The calcite crystals are hard and cannot be cleavaged or scratched easily. Using these crystals with the limestone, without sorting, decreased the production of the kiln to about 900 mtpd, while under normal operation 1,520 mtpd can be achieved. Al-laterite and iron ore are used as corrective materials. A new raw material deposit is under prospect, nearby the existing quarries. The data collected from the plant is attached herewith.

Raw Materials Problems:

1. When limestone mined from the quarry contains high amounts of calcite and quartz crystals, the kiln feed becomes harder to burn causing a drop in kiln production. The clinker becomes dusty.
2. Kiln feed has very high fines (less than 20 microns is 60%) which creates high dust and recirculation of fine materials in the preheater system. About 20% is the amount of dust which is lost through the stack in most of the cases.

Observations: The limestone deposits are relatively hard and variable where high and low grade of limestone can be mined and are stored separately. Crystals of calcite and quartz are found as intrusions between the limestone with different thickness. They cannot be separated from each other and/or the limestone. Previous studies show that the raw meal has:

1. Quite high level of quartz as its size is much more than 44 microns. Some particles reach 413 microns.

2. Calcite crystal is much more than 125 microns and its maximum size is 575 microns.

Thirty-two percent of total quartz is present above 44 microns and 13.4% of total calcite is present above 90 microns. The minor oxides (alkalies, SO_3, Cl and P_2O_5) are within the acceptable limits for a dry process.

Although the kiln feed has residues of 15 - 20% on 170 mesh and 3.4% on 72 mesh, which is considered very high, it has a very high fines (about 20 microns is 60%), according to A.C.C. studies.

Discussion and Recommendations: The raw mix has approximately 13% SiO_2 with 80% of this amount free of SiO_2 (quartz) and adding to it the presence of calcite crystals. The presence of this high percentage of free SiO_2 upsets the burnability and the reactivity of the mix, requiring high burning temperature (which cannot be achieved due to poor coal quality). This necessitates slow kiln operation which results in low clinker production. Add to this the presence of calcite crystals (pure $CaCO_3$) with an appreciable amount and larger particle size and the inconsistent particle size distribution of the raw mix. Although the A.M. of the clinker is in the range of 1.2, yet the liquid phase is 26% which is considered low for such a raw mix, containing high amounts of pure quartz and calcite crystals. All these are detrimental to the burning processes and operation, and lifetime of bricks (180 days). It is recommended:

1. Use minimum amount of calcite and quartz crystals in the kiln feed. In this respect, selective quarrying and sorting (from the belt conveyor after the primary crusher) these materials to the percentage which can be tolerated in the kiln. Apply the computer technology for quarry operation in the case of the new quarry for sorting and selecting the materials with low calcite and quartz crystals.
2. The ball charge of the raw mill should be checked and adjusted for better particle size distribution of raw meal.
3. Perform different burnability tests with different mix designs and particle size distributions, considering the clinker (after the ash contributions) is in the range of:

S.M.	2.2	C_3S	50
A.M.	1.2	C_2S	25
H.M.	2.1	C_3A	7
L.S.F.	92%	C_4AF	12
C/S	3.1	L.P.	28%

In the case of higher calcite and quartz present in the raw mix, it is preferable to use some iron ore as a flux to ease the sintering process and to increase the liquid phase. Transfer the best burnability and clinker composition to the plant production after adjusting the particle size distribution of the mill product similar to that of the lab studied.

4. The percent of the dust is very high (20%), it is recommended to check the design of the cyclone (first stage) and modify it to decrease the amount of dust emitted from it.
5. Increase the liquid phase in the clinker to about 28% to decrease the dusty clinker and improve burnability. Also, decrease the fineness of the kiln feed to approximately 15% on 170 mesh (or less) and 1.8% on 72 mesh for better clinkerability and reactivity.
6. Perform X-ray diffraction and mineralogical studies on the calcite and quartz crystals and the kiln feed with different composition. Identify the limits of these crystals which can produce better quality and optimum kiln production.
7. Feed the kiln with consistent kiln feed (±0.2% $CaCO_3$) taking into consideration the dust added to the system; qualitatively and quantitatively.
8. Dust, in the case of its use, should be blended with the mill product in the blended silo. No dust will be allowed to the kiln feed without blending. Dust handling should be engineered carefully.
9. Although coal is partially blended, it is recommended to be completely blended by a stacker reclaimer. A supply for 10 - 15 days should be available. Characterize the coal before feeding it to the kiln and adjust the kiln feed accordingly. Dry coal with ash content less than 30% and a temperature of 1,425 - 1,500°C is highly recommended. Particle size of coal to the kiln should be adjusted to the optimum.
10. Determine minor constituent on a regular basis for raw materials, kiln feed clinker, coal and coal ash.
11. Flame shape required to be adjusted using adequate coal fineness, the correct amount of primary air and avoid flame impingement.
12. Establish a process control in the plant using an X-ray spectroscopy to control the kiln feed. It is preferable to use CaO content rather than $CaCO_3$ content.
13. Dust from different collecting points should be completely analyzed for alkali, carbonate, SO_3 Cl, etc. Its quantity also should be determined. Actions should be taken to reduce the present amount of dust to 7 - 8%.
14. It is highly recommended to study the clinker by microscope techniques, evaluate the crystals' shapes, sizes, burning and cooling process and

relate these to the cement properties. Optimum quality and operation can be obtained by this study.

15. The power consumption is 130 - 133 kwh/t of OPC cement ground at 2,900 cm^2/gm. It is highly recommended to have an energy audit through all the plan to study possibilities of saving energy at different production points.
16. Fuel consumption is 950 kcal/kg clinker which is considered high. One of the factors for high fuel consumption is high free SiO_2 and low liquid phase. Besides, there is some kiln equipment which is not operated satisfactorily. In this respect, it is requested to adjust and operate all the kiln equipment for smooth operation and controlling all the parameters. Stop all the leakage points of air.
17. In the case of using mineralizers, it is recommended to use a materials which has no adverse affect on the preheater and kiln operations and on the clinker quality. It should also be economical and available. It is recommended to perform a lab study on such a material, followed by a pilot plant evaluation and clinker and cement characterizations.

Note: A vertical mill is under installation to grind the raw materials which will be supplemented by the existing raw mills and feed the existing kiln after its conversion to precalciner system. This means that two different particle size distributions (as it is known that each mill produces product with different particle size) will be produced. Besides, considering the affect of calcite and quartz crystals, hence it will be expected some operational difficulties unless the product of both mills will be blended continuously and with the same ratio all the time.

DURGA CEMENT WORKS
DURGAPURAM

Information Collected

Raw Materials: Limestone (78 - 86% $CaCO_3$) exists in different properties in the same quarry where medium and high grade can be obtained. The medium grade has an average of 80%, while the high grade has 86% $CaCO_3$. SiO_2 contents are 15% and 10% for both low and high grade limestone. Both low and high limestone grades are fed separately to the plant. Cl, SO_3, Na_2O and K_2O are in the permissible limits. The limestone has a moisture of 5 - 8% and with 6.86 B.W.I. It is dense and nonporous. Detailed study on prospection of the raw materials is underway for a nearby deposit which is closer and similar to the operating quarry. Al-laterite and iron ore are used for the limestone correction. Calcite and quartz are found between the limestone layers.

% By Weight

	Limestone (Average)	Al-Laterite	Iron Ore
SiO_2	13.00	7.12	1.84
Al_2O_3	2.30	43.20	0.58
Fe_2O_3	0.70	26.10	95.22
CaO	46.88	0.86	1.06
MgO	0.30	-	0.08
SO_3	0.16	-	-
K_2O	0.17	0.03	0.41
Na_2O	0.06	0.02	0.15
L.O.I.	36.76	19.80	0.66
Total	100.33	97.13	100.00
Cl	0.01		
$CaCO_3$	84.50		
Total Alkalies	0.23		

Free SiO_2 $\simeq$ 10.00 (11% at lower level of limestone).

The limestone is variable with different thickness of pockets and layers of hard pure calcite crystals (hard to be cleavaged by hand) in close contact with quartz crystals. Pyrite spots can be observed with the limestone.

Kiln Feed: With percentage of 94 : 5 : 1 limestone : Latrite : Iron Ore.

	% By Weight		
SiO_2	12.84		
Al_2O_3	3.10		
Fe_2O_3	3.13		
CaO	44.17		
MgO	0.67	S.M.	: 2.06
SO_3	-	A.M.	: 0.99
K_2O	0.18	H.M.	: 2.32
Na_2O	0.08	L.S.F.	: 105%
L.O.I.	35.42		
Total	99.59		
Free SiO_2	9.9		
$CaCO_3$	79.00		
$MgCO_3$	0.36		
Cl	0.015		

Fineness: 15 - 20% on 170 mesh and 3 - 4% on 72 mesh

Clinker:

SiO_2	22.52		
Al_2O_3	5.90	S.M.	: 2.14
Fe_2O_3	4.60	A.M.	: 1.24
CaO	64.40	H.M.	: 1.95
MgO	1.42	L.S.F.	: 0.89
SO_3	0.67	C_3S	: 44
K_2O	0.36	C_2S	: 29
Na_2O	1.08	C_3A	: 7
L.O.I.	-	C_4AF	: 14
Total	100.95		
		L.P.	: 26% (at 1,335°C)
		C_3S/C_2S	: 1.52
F.L.	0.76		
C.L.W.	1,150		

Process: One kiln using the suspension preheater system (4-stage) started in 1983 to produce 1,350 mtpd. The limestone is crushed in 2 stages: primary with a capacity of 480 mtph and a secondary with a capacity of 250 mtph. Grinding of the raw materials takes place in a ball mill with a capacity of 125 mtph. The blending system is a batch type with 100% blending efficiency. Indirect firing system is used for sintering the raw mix in a 4.35 m (diameter, inside shell) x 66 m (length) kiln. The utilization factor of the kiln is 100% with capacity ranges from 1,300 - 1,350 mtpd clinker and 950 kcal/kg clinker. The clinker is cooled by a grate cooler.

Some Operational Data: Primary air: 15 - 16%
Back end kiln temperature: 950 - 1,000°C
Burning zone temperature: 1,350 - 1,400°C
Preheater gas oxygen: $\simeq$ 6.0%
I.D. fan temperature: $\simeq$ 320%

Coal:	C	56.35%
	H	4.73%
	N	1.14%
	O	37.19%
	S	1.00%
	Moisture	5.74%
	Ash	30.50%
	H.H.V.	5,380 kcal/kg
	L.H.V.	4,200 kcal/kg
	SiO_2	57.14
	Al_2O_3	26.84
	Fe_2O_3	6.82
	SO_3	2.06
	Others	7.00

Coal Fineness: 18 - 20% on 170 mesh and 2 - 3% on 72 mesh.

Fuel Consumption: 950 kcal/kg

Ash Contribution to Clinker: $\simeq$ 6.86%

Dust Collectors: ESP and a conditioning tower ahead of it.

Percent of Dust: 19 - 20%

Dust Collected: The dust is recirculating to the system along with kiln feed.

Lifetime of Brick Lining: 150 days

Thickness of Coating: 4 - 9" irregular

<u>Clinker Quality</u>: 40.0% with -1 mm and 12.0% with +30 mm

<u>Total kwh/t of Cement</u>: 130 - 133 kwh/t of OPC cement ground at 2,900 cm^2/gm in open circuit cement mill.

<u>Problems</u>:

1. Production of kiln decreased to 900 mtpd when the quarry face was changed, where some calcite and quartz crystals were mined with the limestone.

2. High amount of dust (19 - 20%) which is very fine, with 9.00%, 1.60%, 4.25%, 45.70%, and 36.50% for SiO_2, Al_2O_3, Fe_2O_3, CaO and L.O.I. It has 0.4% residue on 170 mesh and 0.0% residue on 72 mesh.

DURGA CEMENT
DURGAPURAM

Names of the persons who participated in discussion from Durga Cement.

1.	Dr. M. P. Jain	Managing Director
2.	Mr. V. B. R. Suryam	Chief General Manager (R&D)
3.	Mr. G. K. Maheshwari	Chief Executive (Works)
4.	Mr. D. B. N. Rao	Dy General Manager (R&D)
5.	Mr. C. Sudhaker	Manager (Process & Quality Control)
6.	Mr. A. K. Varma	Senior Chemist
7.	Mr. M. Dayanand	Chief Burner
8.	Mr. K. Siva Ramakrishnaiah	Sr. Mines Manager
9.	Mr. V. C. Nagabhushanam	Geologist

Names of NCB Counterparts.

1.	Dr. P. B. Rao	Scientist
2.	Mr. A. D. Agnihotri	Mining Engineer

MADRAS CEMENTS LIMITED
RAMASWAMY RAJANAGAR

Madras Cements Limited is located at Ramaswamy Rajanagar, Division Kamerajan. The plant started in 1961 by 200 mtpd wet process and with another wet kiln in 1963. In 1977 suspension preheater kiln was commissioned, and the wet kilns were consequently stopped. The SP system kiln, of FLS design; with a designed capacity of 1,200 mtpd, of which 1,140 mtpd has been obtained. The utilization factor of the kiln is about 99%. All the information gathered from this plant are attached herewith.

Raw Materials and Coal: The raw materials deposits are contaminated with ignious rocks which showed by X-ray diffraction that it consists of different minerals which are: biotite, muscovite, feldspar, quartz, iron minerals, Ca-Mg-silicate, diaspore, talc, clay minerals, dolomite, tremolite and graphite. The ignious rocks are found as rounded pockets with different diameters inside the limestone. They cannot be disregarded in the quarry during blasting the limestone or by selective quarrying. Sorting this material takes place after the primary crusher. These materials cause the raw mix to be hard burning, upset the kiln, reduce the kiln production and increase the fuel consumption. The limestone is variable in composition and its mineralogical composition is calcite (mainly), quartz, muscovite, kyanite, microcline, enstatite, dolomite, hornblende, biotite and gibbsite. In the case of hard burning mix, the intensity of muscovite, kyanite, microcline, enstatite and hornblende are increased markedly. Also the loss on ignition is decreased.

A geological study for the limestone deposits was completed in 1981 and a new study is under way, as the previous study showed that the reserves are only 11 million tons. About 2 tons of waste materials, mostly intrusions, are wasted for each one ton of limestone. Coal from different sources including imported from Australia is used to increase the heating value and decrease the ash content. Coal with 30 - 42% ash content is mostly used, with a heating value about 4,000 kcal/kg.

There is no preblending and blending system for the limestone and coal respectively. The blending system of kiln feed is not highly efficient.

Madras Cement Limited is considered the best plant of all eight plants visited during this mission. Credit should be given to this plant for having;

1. A good selective quarrying system. They intend to operate the quarry by a computer.
2. A good crushing system where the ignious rocks are picked up from a belt conveyor by hand on both sides, after crushing the limestone in a primary crusher.
3. An X-ray fluorescence and X-ray diffraction for analysis of the raw materials, raw meal, kiln feed chemically and mineralogically. X-ray fluorscence is not on line.
4. A good process and quality control system, and the possibility of adjusting the kiln feed to a narrower deviation, although the blending factor is inefficient and X-ray analyser not on line.
5. A clean plant with 7 - 8% dust, where all the dust particles are collected leaving only clean stack gas.
6. Theoretical mineralogical composition of the clinker falls within the standard requirements for ordinary portland cement clinker; high C_3S and low C_2S.
7. Good figure for kwh/ton of cement (108 - 103).

Kiln Production With Regard To The Raw Materials: When the amount of the ignious rocks increases above certain limits (3-4%) in the kiln feed, it becomes very hard to be sintered. No changes in the flux contents is considered when the amount of these rocks is increased. This causes less kiln production.

Recommendations:

1. Keep the clinker parameters after ash absorption in this range:

S.M.	2.3 - 2.5
A.M.	1.3 - 1.5
H.M.	2.05 - 2.15
L.S.F.	0.92 - 0.94
C_3S	52%
C_2S	25%
L.P.	28%

Perform burnability tests on different mix designs within the above ranges and compare it with the easy-burning mixes. Select the best mix which can tolerate the maximum amount of ignious rock and sinter it in the rotary kiln. Consideration to be taken that high amounts of this ignious rocks needs some flux and especially iron ore. 3 - 5% of these materials is considered a good figure to be used, otherwise the liquid phase will be increased causing some difficulties in the kiln and clinker grinding. However, in each case trials for each mix should be burned after burnability test in a pilot plant to study the quality of the clinker and the produced cement.

2. Use a coal with low ash content and up to 30% maximum and with heating value of about 5,000 kcal/kg in order that the sintering temperature can be obtained.
3. Coal should be blended and a supply for 10-15 days should be available. Shale in coal should be removed and the coal should be dried in order that coal with about 1% moisture should be fired in the kiln. Characterize the coal before feeding it to the kiln and for the secondary firing and adjust the kiln feed accordingly.
4. Particle size of the kiln feed and coal for each of the kiln and secondary firing should be adjusted to the optimum.
5. Determination of minor constituents are required on a regular basis for raw materials, kiln feed, clinker, coal and coal ash.
6. As the lignite is high in sulphur content, it is necessary to use a small amount of it in order not to increase the total SO_3 in the system. Contaminated shale should be sorted and removed. It is advantageous to have ash content less than 30% and a high heating value to obtain the burning temperature.
7. The raw materials feeding to the plant are controlled by removing the black stone. It is highly recommended to control the other process and ensure continuous, homogenous supply of kiln feed and accordingly stable kiln operation with higher capacity and maximum quality. It is recommended to have:
   - A preblending system for limestone; covered is preferable.
   - Blending system for coal; covered is preferable.
   - Cooling the clinker to a lower temperature. A rotary cooler supplemental to the existing planetory cooler is suggested or a grate cooler. A study for each case should be completed.
   - The existing blending system has some operational problem, it should be put in right operation.
   - It is better to have two fan systems for the plant instead of one fan system to better handle the I.D. fan gas when the raw mill is working and to completely dry the raw materials.
   - Weight feeder for coal supply to the kiln.
   - Kiln inlet sealing should be changed to prevent the leakage air and bring the fuel consumption down.
   - Stop all the leakage air points, adjust the percent of primary air and avoid flame impingement.

- Use dry coal for burning and secondary firing to reduce fuel consumption. Study all the possibilities to reduce fuel consumption to about 850 kcal/kg clinker.
- Check the ball charge size and distribution of the raw mill.

8. It is advisable to attach the X-ray machine (using the X-ray fluorscence) on line with a modern process control, to control the kiln operation.
9. The kwh/t of coal grinding in the coal mill is relatively high. Consideration should be taken to reduce it ($\simeq$ 40 kwh/t).
10. It is highly recommended to study the clinker by microscope techniques, evaluate the crystals' shapes, sizes, burning and cooling processes and relate these to the cement properties. Optimum quality and operation can be obtained by this study. There is no doubt that more than 1,200 mtpd will be achieved.
11. It is advisable that the cement exiting the cement mill does not exceed 110°C.

MADRAS CEMENTS LIMITED
RAMASWAMY RAJANAGAR
KAMENAJAR DIVISION

Information Collected

Raw Materials: The limestone deposits are approximately 22 km from the plant. Three quarries are operating at the same time which are:

1. Source 1: with 77.00 - 82.41% $CaCO_3$, which is considered the main quarry.
2. Source 2: with 75.16% $CaCO_3$.
3. Source 3: with 72.61% $CaCO_3$.

Besides sweeteners with 85.66% $CaCO_3$, bauxite from two different sources and iron ore are used. Properties and chemical analysis of the raw materials are given in Table I.

Igneous rocks (black stone) are mixed and intruded with the limestone. This cannot be separated except after crushing and hand picking on the conveyor belt.

Kiln Feed: 82 - 86 limestone (from all the 3 sources): 2.8 sweetner; 8 - 13 clay; 2.8% bauxite. Two different raw mixes are encountered at Madras Cement Company. One is easy burning mix, which has 3 - 4% of the igneous rocks mixed with the limestone while the hard one has more than 4% of black stone. The analysis of each is as follows:

Kiln Feed - Percent By Weight

	Easy-Burning	Hard-Burning
SiO_2	11.81	11.86
Al_2O_3	2.82	2.76
Fe_2O_3	2.18	2.24
CaO	45.07	44.81
MgO	1.90	1.90
SO_3	-	-
K_2O	-	-
Na_2O	-	-
L.O.I.	36.06	35.60
Total	99.84	99.17
S.M.	2.36	
A.M.	1.29	
L.S.F.	1.19	

$CaCO_3$ 77.25 - 78.00%

Fineness 14 - 16% on 170 and 1.6 - 2.0 on 72 mesh

Cl 0.015 max

Free SiO_2 5.5 - 6.0%

Total Alkalies 0.7 - 0.8 max

As can be seen, hard burning raw mix is characterized by low L.O.I. in comparison to easy burning mix, although there is not much variation in chemical constituents.

Blending System: Gravity blending system with 3-4 : 1 blending factor.

Clinker:	SiO_2	21.46
	Al_2O_3	5.99
	Fe_2O_3	3.04
	CaO	65.46
	MgO	2.04
	L.O.I.	0.74
	S.M.	2.38
	A.M.	1.97
	H.M.	2.15
	L.S.F.	0.94
	C/S	3.05
	C_3S	47.31
	C_2S	26.11
	C_3A	10.74
	C_4AF	9.24
	L.P.	29.15
	C_3S/C_2S	1.81
	C.L.W.	1,200 - 1,300
	F.L.	$\simeq$ 2%

Process: A suspension preheater system started in 1977 designed by Larsen and Tubro Limited (L&T) using F.L.S. design. The kiln is 4.35 m (inside shell) x 64 m length design to produce 1,200 mtpd, but 1,140 mtpd has been obtained. The utilization factor of the kiln is about 99%. The kiln is provided with secondary firing at the riser duct from kiln to the cyclones with percent of 20% and 80% in the kiln. Raw materials are ground in a closed-circuit ball mill producing 115 mtpd with fineness of 14 - 16% on 170 mesh and 1.6 - 2.0% on 72 mesh. The raw mill has three hoppers:

1. For bauxite
2. For low grade limestone + clay

3. For high grade limestone + sweeteners

The plant is designed for one fan system. When the mill is running, only 40% of the preheater gases can be handled, to dry up to 2 - 3% moisture in the raw materials. The kiln is working on two tyres only and the clinker is cooled by a planetary cooler. Coal from different sources is used to improve the quality of local coal. The coal feeding the kiln has a high moisture which affects the burning process, besides it has a variable percent of ash (30.0 - 41.0%).

Some Operational Parameters:

Oxygen after I.D. fan	: 4.6%
Oxygen at kiln inlet	: 4.5% due to the secondary lining
Stage I temperature	: 380°C
Stage II temperature	: 550°C
Stage III temperature	: 710°C
Stage IV temperature	: 820°C
I.D. fan temperature	: 368°C
CO at ESP inlet	: 0.25%
CO after I.D. fan	: 0.01%
Percent of primary air	: $\simeq$18%
Back end temperature	: 950 - 1,000°C

Firing System: Indirect

Coal: Bituminous coal with about 20% imported Australian Coal

H_2O: 3.00 - 4.74%

Volatile matter: 25.4 - 27.7%

Ash: 30.16 - 41.80%

Fixed C: 26.00 - 39.70%

Ash Analysis:

SiO_2	62.46%
Al_2O_3	22.57%
Fe_2O_3	7.97%
CaO	4.22%
MgO	1.12%
K_2O	0.656%
Na_2O	0.361%
SO_3	1.41%

Particle Size of Coal: 15 - 20% on 170 mesh and 3% on 72 mesh

Coal Consumption: $\simeq$ 20%

% Ash Contribution to the Clinker: $\simeq$ 6%

Fuel Consumption: $\simeq$ 950 kcal/kg

% of Dust From Kiln: 7 - 8%

Type of Dust Collector: ESP with conditioning tower

Dust Collected: Is usable and mixed with the kiln feed without blending

Clinker Quality: 40% with -3 mm and 10% with -25 mm

kwh/t Cement: Ranges from 108 - 103

Problems:

1. Blending system inefficient, with a great variation in CaO content.
2. Moisture problem in limestone and clay.
3. Coal without blending system and no weight feeder for coal. Coal has a high moisture which cannot be completely dried.
4. Velocity and primary air cannot be controlled.

Table I

Properties and Chemical Analysis of Raw Materials

Percent By Weight

	L.S. Main Quarry		L.S. Source	L.S. Source	Sweet-ener	Bauxite			Iron
	Range	Average	2	3	L.S.	Clay	Al	Mysore	Ore
$CaCO_3$	82.41-77.07	79.75	-	-	-	51.36	-	-	-
$MgCO_3$	-	1.26	-	-	-	1.98	-	-	-
Moisture	1	-	-	-	-	-	-	-	-
B.W.I.	13-16	-	-	-	-	-	-	-	-
SiO_2	9.77-13.32	12.27	14.49	12.56	5.56	28.87	9.85	7.76	4.04
Al_2O_3	1.03- 1.88	1.74	2.30	1.72	0.90	6.30	41.84	52.24	0.50
Fe_2O_3	1.14- 1.84	1.34	1.78	2.74	3.08	3.65	25.37	11.55	92.00
CaO	46.20-48.56	47.43	45.31	45.67	50.58	31.93	-	-	Nil
MgO	1.11- 1.71	1.30	1.42	2.38	1.45	1.97	-	-	0.66
SO_3	Nil	Nil	Nil	-	Nil	-	0.57	-	
K_2O	0.30	-	0.30	0.30	Nil	0.30	0.175	-	-
Na_2O	0.70	-	0.70	0.70	Nil	0.40	0.175	-	-
L.O.I.	34.34-36.50	35.15	34.20	34.52	38.56	22.56	21.58	27.8	2.16
Free SiO_2	4.40- 8.71	-	8.79	4.01	0.71	20.19	-	-	-
Cl	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.D.: Not determined.

MADRAS CEMENTS

RAMASWAMY

Names of the persons who participated in discussions from Madras Cements.

1.	Mr. Natarajan	General Manager
2.	Mr. S.P.D. Janardhan Rajha	Manufacturing Manager
3.	Mr. H.V. Sethuram	Mines Superintendent
4.	Mr. R. Murugan	Manager (Quality Control)
5.	Mr. Velaguthan	Works Engineer

Names of NCB Counterparts.

1.		Scientist
2.	Mr. A.D. Agnihotri	Mining Engineer

Annex 10

EXPERT APPRAISAL

UNDP PROJECT IND 84 020 ON "STRENGTHENING NCB CAPABILITY IN PRODUCTIVITY ENHANCEMENT OF CEMENT INDUSTRY (PEP)"

EXPERT : George R. Gouda
JD : Annexure I
WORK PLAN : Annexure II

NCB Counterparts:
(i) Mr. T. N. Verma
(ii) Dr. S. N. Yadav

Name and Location: Shree Digvijay Cement, Sikka (Gujarat)

PRODUCTIVITY ENHANCEMENT ASPECT
Main Points - Details in the Plant Report

Sl No	Subject covered in first mission	ASPECTS COVERED			Outcome in terms of Project Objectives	
		Diagnosis	Methodology	Implementation	Achieved	Expected
1	2	3	4	5	6	7
1	Raw materials; limestone and sandstone	High quality of limestone, sandstone high in SiO_2. No amount of free SiO_2 is available	Certain amount of free SiO_2 can be tolerated in sintering the kiln	Determine free SiO_2 and the minor constituents	Recommendations were discussed and made	Better understanding the raw materials
2	Raw mix and clinker quality	Unbalanced raw mix, inefficient blending system, variable kiln feed, high free-lime and expansion	Maintain good blending system and a balanced raw mix	Good blending system with narrow variations in kiln feed	Recommendations were discussed. Parameters were given	Better kiln operation and high quality of clinker

1	2	3	4	5	6	7
3	Ring formation at the junction of preburning and burning zones	Not a continuous process and occupies about 2.0 m. Kiln diameter is relatively small	No detailed study on the composition analysis. It is expected to be spurrite formation	Investigate the composition of the ring and all related variables (coal kiln feed, kiln operation)	Reason of Ring formation were discussed. Recommendations were given. This is mainly due to unstable feed, coal and operation	Improvement in kiln operation and no ring formation
4	Method of using dust collected	It is added to the kiln feed without blending	To analyze and study the dust collected from different points	Determine the effect of adding dust from different points	Recommendations were given as well to stop feeding the kiln with C.T. dust	Stable kiln operation, good clinker quality and homogeneous product
5	Coal:unhomogenous, ash content particle size distribution, etc., and flame shape	Limited amount of coal, high ash content, variable quantities, high fineness, etc. Flame shape is impingement	Good supply of coal, constant quality with its characterization before firing	Determine the optimum particle size for better flame, supply 10 - 15 days, blending the coal	Recommendations were discussed	Enhance the production, constant ash absorption
6	Clinker microscopy for quality control. Oil well cement and type V cement	Discussions with the plant personnel. Recommendations were given.				

EXPERT APPRAISAL

UNDP PROJECT IND 84 020 ON "STRENGTHENING NCB CAPABILITY IN PRODUCTIVITY ENHANCEMENT OF CEMENT INDUSTRY (PEP)"

EXPERT : George R. Gouda
JD : Annexure I
WORK PLAN : Annexure II

NCB Counterparts:
(i) Mr. T. N. Verma
(ii) Dr. S. N. Yadav

Name and Location: Saurashtra Cement and Chemical Industries, Ranavav (Gujarat)

PRODUCTIVITY ENHANCEMENT ASPECT
Main Points - Details in the Plant Report

Sl No	Subject covered in first mission	ASPECTS COVERED			Outcome in terms of Project Objectives	
		Diagnosis	Methodology	Implementation	Achieved	Expected
1	2	3	4	5	6	7
1	Raw materials; limestone and clay	High variation in quality. Free SiO_2 is not available	Free SiO_2 determination	Determine the free SiO_2 for the raw materials	Recommendations were given	Better understanding the raw materials
2	Raw mix and clinker quality	High residue on the raw mix, high free lime in clinker (4%) and unbalanced clinker, poor quality	Maintain good balanced raw mix and an efficient blending system	Adjust the kiln-feed. Feed the kiln with chemically constant mix. Parameters were given and explained	Recommendations were given	Better kiln operation and high quality of clinker
3	I.D. fan building mesh	High Fe_2O_3, Al_2O_3 and SiO_2. Low in CaO, contains some minor constituents	To change the temperature profile of SP and PC system	To use clay which can be ground coarser and keep the fineness lower	Recommendations were given	No fan build-up if there is no other mechanical and/or design problems

1	2	3	4	5	6	7
4	Variable calcination in precalciner	Varies from 66 - 84%. CO% exit PC is relatively high	To feed the kiln with homogeneous feed	Good blending and quality control of kiln feed	Recommendations were given	Stable PC operation and lower free lime in the clinker
5	Dust handling	It is added to the kiln feed without blending	To study the dust composition from different points	Determine the affect of adding dust on kiln operations	Recommendations were given	Stable kiln operation, good clinker quality
6	Coal	Variable, high ash content some particle size is fed to kiln and PC	Good supply of coal, constant quality	Blending the coal and determine the optimum particle size to kiln and PC	Recommendations were given	Enhance the production, control ash absorption
7	Clinker microscopy, total power consumption and quality control	Discussions with the plant personnel. Recommendations were given				

EXPERT APPRAISAL

UNDP PROJECT IND 84 020 ON "STRENGTHENING NCB CAPABILITY IN PRODUCTIVITY ENHANCEMENT OF CEMENT INDUSTRY (PEP)"

EXPERT : George R. Gouda
JD : Annexure I
WORK PLAN : Annexure II

NCB Counterparts:
(i) Mr. A. Pahuja
(ii) Dr. K. V. Mathur

Name and Location: Cement Corporation of India Limited, Nayagaon (Mandsaour)

PRODUCTIVITY ENHANCEMENT ASPECT
Main Points - Details in the Plant Report

Sl No	Subject covered in first mission	ASPECTS COVERED			Outcome in terms of Project Objectives	
		Diagnosis	Methodology	Implementation	Achieved	Expected
1	2	3	4	5	6	7
1	Raw materials: limestone, sweeteners and laterite	Limestone is marginal and sweetener is added where supply is not continuous	Sweetener is necessary	Guarantee for continuous supply of sweeteners is required	Recommendations were given	To improve the mix design
2	Raw mix and clinker quality continuous	Low A.M., H.M. L.S.F. and C/S ratio. C_3S/C_2S in the clinker is less than 1. High free lime, clinker ball with different color. Free silica high in the raw mix	To balance the mix design as it is given in the report. Increase CaO and decrease SiO_2. Decrease free SiO_2	Feed the kiln with homogenized feed and with the right fine-ness	Recommendations were given and also the raw mix parameters	Smooth kiln operation, and better clinker quality

1	2	3	4	5	6	7
3	Method of using collected dust	It is added to the kiln feed w/o blehding	To analyze and study the dust collected from different points	Determine the affect of using the dust on the clinkers quality. Repair the conditioning tower	Recommendations were given	Stable kiln operation, good clinker quality and homogenous product with low F.L.
4	Kiln operation, fuel consumption power supply	High amount of leakage and ash from both sides, control instrument of the kiln are not working, and high fuel consumption. Interrupted power supply	Complete maintenance and cleaning the plant. Put all the equipment in a satisfactory operation	Acquire the necessary spare parts as soon as possible. Power should be guaranteed	Recommendations were given	Stable kiln operation, reduction in fuel consumption
5	Coal	Variable, high ash content and fineness	Study optimum particle size	Blend the coal and carry out experiments	Recommendations were given	Stable kiln operation with maximum efficiency
6	kwh/t of cement	Is about 147 kwh/t cement	Check different points for energy saving	Energy audit	Recommendations were given	Reduction in energy consumption
7	Clinker microscopy, burnability test, free silica	Discussions with the plant personnel. Recommendations were given				

EXPERT APPRAISAL

UNDP PROJECT IND 84 020 ON "STRENGTHENING NCB CAPABILITY IN PRODUCTIVITY ENHANCEMENT OF CEMENT INDUSTRY (PEP)"

EXPERT : George R. Gouda
JD : Annexure I
WORK PLAN : Annexure II

NCB Counterparts:
(i) Mr. A. Pahuja
(ii) Dr. V. K. Mathur

Name and Location: Lakshmi Cement Plant, Jakhaypuram (Banars)

PRODUCTIVITY ENHANCEMENT ASPECT
Main Points - Details in the Plant Report

Sl No	Subject covered in first mission	ASPECTS COVERED			Outcome in terms of Project Objectives	
		Diagnosis	Methodology	Implementation	Achieved	Expected
1	2	3	4	5	6	7
1	Raw materials: limestones (high and low grade)	Clay, quartz and silicious materials are mixed with the limestone. Hetrogeneous deposits	Effective selective quarrying	Good prospection of raw materials and using computer for quarrying operation		Smooth quarrying operation and selected materials for the raw mill
2	Raw mix and clinker quality	Raw mix is unbalanced, low S.M., high A.M., low L.S.F., high L.P., high fineness. Clinker variable high F.L.	Raw mix should be balanced, using sweeteners and iron ore. increase SiO_2 content	Good design of raw mix and perform burnability tests. Decrease liquid phase	Recommendations were given	Good quality of clinker and smooth kiln operation

1	2	3	4	5	6	7
3	Cyclone jamming, S.P. and kiln sizing	Soft powder material, no detailed information is available. Temperature and draft are low	Study the material carefully and stable kiln operations	Increase the temperature profile, especially cyclone III. Stable kiln operation. Adjust S/K ratio	Recommendations were given	Smooth operations without jamming
4	Method of using collected dust	Dust is added to kiln feed without blending	Study and analyze the dust collected from different points	Determination of the effect of adding dust	Recommendations were given	Stable kiln operation and good clinker quality
5	Coal: homogeneity, ash content, particle size and flame shape	30% ash content, good reserve and no blending system	To characterize the coal and determine the optimum particle size	Perform the required test	Recommendations were given	Stable kiln operation, enhance production, decrease fuel consumption
6	Ideal raw mix, raw and cement mills, ball charge, clinker size and grindability, blending and clinker microscopy	Discussions with the plant personnel. Recommendations are given.				

EXPERT APPRAISAL

UNDP PROJECT IND 84 020 ON "STRENGTHENING NCB CAPABILITY IN PRODUCTIVITY ENHANCEMENT OF CEMENT INDUSTRY (PEP)"

EXPERT : George R. Gouda
JD : Annexure I
WORK PLAN : Annexure II

NCB Counterparts:
(i) Mr. A. Pahuja

Name and Location: Shree Cement Limited (Beawar)

PRODUCTIVITY ENHANCEMENT ASPECT
Main Points - Details in the Plant Report

Sl No	Subject covered in first mission	ASPECTS COVERED			Outcome in terms of Project Objectives	
		Diagnosis	Methodology	Implementation	Achieved	Expected
1	2	3	4	5	6	7
1	Raw materials: low and high with average which is feedable limestone. Variable composition	Free SiO_2 (3-8%) in feedable limestone	Selecting the raw materials	To avoid use of high free SiO_2	Recommendations were given	Good burnability of raw mix
2	Preblending of raw materials and blending raw mix	Inaffective and inefficient	Repair or acquire effective systems	High preblending and blending factor	Recommendations were given	Consistent kiln feed
3	Clinker quality	High free lime, C_3S/C_2S is about 1.2. High L.P.	Correct the raw mix design and increase S.M.	Low A.M., high C_3S, low C_2S	Recommendations were given	Quantity of clinker will be improved
4	Method of using collected dust	Dust is added to kiln without blending	Study and analyze the dust collected	Determine the affect of adding dust	Recommendations were given	Homogeneous kiln feed and stable kiln operation

1	2	3	4	5	6	7
5	Coal: homogeneity ash content, particle size and flame shape	30% ash content, dry coal and blended with optimum particle size	To characterize the coal	Perform the analysis required	Recommendations were given	Stable kiln operation, reduction in fuel consumption
6	Clinker microscopy, burning rice husk in the precalciner, minor constituents	Discussions with the plant personnel. Recommendations were given				

EXPERT APPRAISAL

UNDP PROJECT IND 84 020 ON "STRENGTHENING NCB CAPABILITY IN PRODUCTIVITY ENHANCEMENT OF CEMENT INDUSTRY (PEP)"

EXPERT : George R. Gouda
JD : Annexure I
WORK PLAN : Annexure II

NCB Counterparts:
(i) Dr. P. B. Rao
(ii) Mr. A.D. Agnihotri

Name and Location: Panyam Cements and Mineral Industries Ltd.

PRODUCTIVITY ENHANCEMENT ASPECT
Main Points - Details in the Plant Report

Sl No	Subject covered in first mission	ASPECTS COVERED			Outcome in terms of Project Objectives	
		Diagnosis	Methodology	Implementation	Achieved	Expected
1	2	3	4	5	6	7
1	Raw materials: limestone, iron ore and sweetener	No geological studies exist. In 1984 ACC completed this investigation. Two tons of wastes are removed for each one ton. High free SiO_2	Effective selective quarrying	Good prospecting of raw materials	Recommendations were given	Understanding the raw materials deposits
2	Raw mix and clinker quality	80% of total SiO_2 is free SiO_2, high residues on 170 and 72 mesh. Low L.S.F.	Improve the raw mix design	Use more sweetener, decrease free SiO_2 and grind the raw mix finer	Recommendations were given	Good clinker quality and stable kiln operation

1	2	3	4	5	6	7
3	Blending system	Is considered that there is no blending system, resulting in variable kiln feed	Blending system is required	Acquire a high blending system	Recommendations were given	Homogeneous kiln feed
4	Method of using collected dust	It is added to kiln feed without blending	Study and analyze the dust collected from different points	Determination of the effect of adding dust	Recommendations were discussed	Stable kiln operation
5	Kiln operation, fuel consumption, leakage through pyroprocessing	Unstable kiln operation, high fuel consumption and leakage	Feed the kiln with homogeneous feed. Prevent leakage	Blending system, good sealing	Recommendations were given	Low fuel consumption
6	Bottlenecks of the plant	Several bottlenecks from quarry to cement mills	Complete rehabilitation of the plant	Complete heat and material balance	Recommendations were given	Balance the equipment
7	Coal, coal mill and particle size	Coal mill undercapability, variable coal, high ash content	Increase the capacity of grinding the coal	Larger coal mills	Recommendations were given	Optimum coal particle size
8	Clinker microscopy, ideal raw mix, ratio C_3S/C_2S	Discussions with the plant personnel. Recommendations were given				

EXPERT APPRAISAL

UNDP PROJECT IND 84 020 ON "STRENGTHENING NCB CAPABILITY IN PRODUCTIVITY ENHANCEMENT OF CEMENT INDUSTRY (PEP)"

EXPERT : George R. Gouda
JD : Annexure I
WORK PLAN : Annexure II

NCB Counterparts:
(i) Dr. P. B. Rao
(ii) Mr. A. D. Agnihotri

Name and Location: Durga Cement Works - The Andhra Cement Company Ltd.

PRODUCTIVITY ENHANCEMENT ASPECT
Main Points - Details in the Plant Report

Sl No	Subject covered in first mission	ASPECTS COVERED			Outcome in terms of Project Objectives	
		Diagnosis	Methodology	Implementation	Achieved	Expected
1	2	3	4	5	6	7
1	Raw materials: medium and high grade limestone, Al laterite and iron ore	Free SiO_2 is about 10% of the total SiO_2 which is 13%. Presence of high % of calcite and quartz crystals	Selecting the appropriate materials	Applying a computer program after geological study of raw materials	Recommendations were given	Understanding the raw materials resources
2	Raw mix, clinker quality, fuel consumption	1. Easy burning mix with little amount of calcite and quartz crystals 2. Hard burning mix with high amount of calcite and quartz xtals 3. High fuel consumption	Determining the high % of crystals which can be tolerated in kiln. Stop leakage of air	Perform burnability tests or adjust the mix design. Check all the kiln instruments	Recommendations were given	Understanding the raw mix composition and stable kiln operation with low fuel consumption

1	2	3	4	5	6	7
3	Raw mix fineness, dust emitted	High residue on 170 and 72 mesh. Dust emitted is very high	Adjust particle size distribution. Check preheater design	Check ball mill charge and ball size. Adjust cyclone I	Recommendations were given	Adjust kiln fineness and reduce dust emitted
4	Dust collected	It is added to the system without blending	Blended dust with the kiln feed after studying it	Good blending system	Recommendations were given	Stable kiln operations homogeneous quality
5	Coal ash, particle size and quantity	Variable coal, high ash and particle size	Blend coal and determine optimum size	Blended system and perform different experiments	Recommendations were given	Stable kiln operation
6	Power consumption	130 kwh/t cement	Energy audit	Review all the power consumption	Recommendations were given	Decrease power consumption
7	Clinker microscopy and burnability tests	Discussions with the plant personnel. Recommendations were given.				

EXPERT APPRAISAL

UNDP PROJECT IND 84 020 ON "STRENGTHENING NCB CAPABILITY IN PRODUCTIVITY ENHANCEMENT OF CEMENT INDUSTRY (PEP)

EXPERT : George R. Gouda
JD : Annexure I
WORK PLAN : Annexure II

NCB Counterparts:
(i) Mr. Alexander
(ii) Mr. A. D. Agnihotri

Name and Location: Madras Cements Limited, Ramaswamy Raja Nagar (Best Plant Visited)

PRODUCTIVITY ENHANCEMENT ASPECT
Main Points - Details in the Plant Report

Sl No	Subject covered in first mission	ASPECTS COVERED			Outcome in terms of Project Objectives	
		Diagnosis	Methodology	Implementation	Achieved	Expected
1	2	3	4	5	6	7
1	Raw materials: limestone with three different $CaCO_3$, sweetener, clay, bauxite and iron ore	Limestone is mixed and intruded with black igneous rock. High % of this rock render sinter the raw mix	Igneous rocks are sorted after the primary crusher		Better burning of raw mix	
2	Raw mix and clinker quality	Most balanced raw mix	To control the amount of the igneous rocks. Perform burnability tests with different percent of igneous rocks and increasing the Fe content		Recommendations were given	Understanding the burnability of igneous rocks
3	Parameters of high burnability of raw mix and fineness	Relatively high liquid phase, good parameters	Parameters were given		Recommendations were discussed	Stable kiln operation

1	2	3	4	5	6	7
4	Coal, variable in quality, high ash content and moisture, particle size	High ash content and feeding the kiln with coarse coal	Dry the coal, grind fine and use high quality coal	Improve the coal mill	Recommendations were given	Better kiln stability and operations
5	Controlling S.P. gases, leakage, clinker microscopy	Discussions with the plant personnel. Recommendations were given				

N.B. This is the best plant visited during the first mission for having:
(1) excellent designed crusher where the igneous rocks are manually sorted,
(2) high quality control system using XRD and XRF.