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ENGLISH

PRODUCTIVITY IMPROVEMENT

THROUGH

CEMENT RAW MATERIALS TECHNOLOGY

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

INDIA

SECOND MISSION

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

Prepared for the Government of India
by the United Nations Industrial Development Organization
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

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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

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

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

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

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

$$C/S = \frac{CaO}{SiO_2}$$

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

$C_2S = 2.867\ S - 0.7544\ C_3S$

$C_3A = 2.65\ A - 1.692\ F$

$C_4AF = 3.043\ F$

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

$= 2.95\ A + 2.2\ F + MgO\ (max.\ 2\%) + Na_2O + K_2O$

I.R. = Insoluble residue

F.L. = Free lime

C.L.W. = Clinker liter weight

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

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

mtpd = metric ton per day

mtpy = metric ton per year

Unfamiliar acronyms, etc.

NCB : National Council for Cement and Building Materials

UPSCC: Upper Paradash State Cement Corporation

SP : Suspension preheater

PC : Precalciner system

CT : Conditioning tower

ESP : Electrostatic precipitator

OPC : Ordinary Portland Cement

PPC : Pozzolanic Portland Cement

LFRM : Loss free raw mix

BWI : Bond Work Index

CC : Percent of calcium carbonate

MC : Percent of magnesium carbonate

ACKNOWLEDGMENTS

My sincere thanks is extended to 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 visits to the cement plants visited during this second mission. Thanks is also extended to the following plants:

Orissa Cement

Gujarat Ambuja

Rajashree Cement

Madras Cement

and their personnel for the assistance, cooperation, friendly atmosphere and fruitful discussions. These made the visit to the above-mentioned plants most successful.

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.

Mission : Second - (First mission was in October and November 1986 for two months.)

Duration : Two and one-half months (January, February through mid-March 1987).

Main conclusions and recommendations

1 Five cement plants were visited durin the second mission. One of these five plants was visited in the first mission (Madras Cement Limited). The objective of the visit is to evaluate the raw materials, raw mix design, flame shape, coal characteristic and clinker quality. These visits were organized by the National Council for Cement and Building Materials.

2 Each of the four cement plants, which were visited during this mission, is using different qualities of raw materials. Three out of these four are controlling the supply from the quarry and continuously testing the quality of the limestome. The fourth plant cannot control the limestone supplied from the quarry due to poor quality control. National Council for Cement and Building Materials should expand its activity for this plant (Dalla Cement) and highly involve in its quarry operation to put this plant in a satisfactory condition.

3 The quality of the clinker which is now produced by Madras Cement has been greatly improved and obtained a high compressive strength. This plant was visited in the first mission and has adopted the recommended changes with regard to the raw mix parameters.

4 Of the other four plants which were visited for the first time during this second mission, all but one plant, which is Dalla Cement, produce clinker of good quality and have a good quality control. One of these plants which is one of the newest plants in India (Gujarat Ambuja) is an

updated plant with closed circuit control and its clinker is a low alkali clinker. Clinker produced from Rajashree Cement is also considered low in alkalies.

5 Cement quality produced from Dalla Cement (by either wet or dry kilns) is of poor quality, has high free lime and expansion. Quality control is very poor, or it can be said does not exist. The plant needs complete rehabilitation, shake-up and structural change. The National Council for Cement and Building Materials should be involved in rehabilitation of this plant, should organize its structure and complete clean-up in order for it to survive. The National Council should set all the parameters for the production and quality control for both wet and dry process.

6 All the plants visited use coal with high ash content, low volatile matters and heterogenous in quality. The flame in some of the plants is long and lazy. It is preferable that the coal ash does not increase than 30%. Blending the coal and optimizing coal particle size for both the rotary kiln and the precalciner are emphasized. Flame should be short and sharp and avoid impingement flame. Primary and secondary airs should be controlled. The National Council for Cement and Building Materials has the capability to provide the required expertise in these subjects to the cement plants.

7 Kiln dust is recycled to the kiln with the kiln feed without preblending, in most of the plants; this causes an erratic variance in the composition. The National Council has the capability to find the application(s) for using this dust. One of its uses is in the production of masonry cement, as it is explained later in this report.

8 One of the cement plants visited during this second mission has mineralizers (fluorine and phosphate compounds) in their raw materials. These materials are not taken advantage of during the burning process. The National Council should advise the cement plants about the application and the percentage of mineralizers used. A study is recommended to be carried out at the National Council using its pilot plant on the type and amount of mineralizer to be used. Complete evaluation of the produced cement should be performed to study if there are any adverse effects on using the mineralizer on each of the raw materials. A discussion on the mineralizer is included later in this report.

9 As the raw materials are variable and usually more than one component is used, it is recommended to preblend the raw materials in a suitable preblending equipment with a high preblending factor.

10 The other recommendations, given in the first report, also apply here and therefore they are not given here.

11 The National Council is equipped with different equipment which is used to characterize the raw materials, clinker, cement and concrete. The Council also is staffed with a highly professional and experienced staff. It is recommended that scanning electron microscopy (SEM) attached to it an energy dispersive x-ray analyzer (EDAX), and other softwares as particle size analyzer, density, porosity and particle shape could be attached to it, and an x-ray diffraction and fluorescence, also must be bought. Modern polarized microscopes with camera attached must also be foreseen. All this equipment is available at the Council but must be updated.

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IV INTRODUCTION

The first mission of this project started in October 1986 for a period of two months. Detailed description of this project and how it was developed is given in the report of the first mission, which is dated December 1986 and is titled:

"Evaluation of mix design, clinker properties and flammability of coal in selected Indian cement plants"

The title of the project is: "Productivity Enhancement and Modernization Program at NCB," and the assignment, which consists of three subsequent missions (each two months) is concerned with productivity improvement through cement raw materials technology. The purpose of the project is "to improve the industry's productivity and the technological level of various units of the cement industry in India by strengthening the National Centre, the National Council for Cement and Building Materials (NCB)."

The first mission covered eight visits to eight different cement plants. Details of these visits are given in the report of the first mission. During this second mission five cement plants were visited; one of these plants was visited in the first mission. The same procedure used in the first mission was followed, where information concerned with the chemistry and properties of raw materials, raw mix, kiln dust, coal and coal ash, clinker quality, clinker absorption of the ash, burning process, flame shape, etc., were collected and discussed. A visit to the various departments, from the quarry to clinker cooler was completed during the visit, accompanied by one or two experts from NCB to strengthen their expertise. After analyzing the constraints which are encountered with each plant and collecting the information according to a questionnaire designed for this project and relating to the raw materials and clinker quality, recommendations were given. These include raw mix design, coal quality, flame shape, burner pipe, operational parameters, etc. For each visit, a report was written including all the information collected and the recommendations to improve the plant efficiency and clinker quality. During this mission, discussions included kiln dust and its application, dusty clinker, mineralizer in cement industry, preblending raw materials, and coal quality. These topics are discussed separately in Chapter VI ACTIVITIES AND OUTPUT.

The plants visited during this mission include:

1 Orissa Cement, Rajgangpur, Orissa
2 Gujarat Ambuja Cement, Keshod, Gujarat
3 Uttar Pradesh State Cement Corporation (UPSCC), Dalla, Mirzapur, U.P.

4 Rajashree Cement, Sedam, Karnataka

5 Madras Cement, Ramasamy Raja Nagar, Tamil Nadu.

Madras Cement was visited during the first mission and recommendations were given to change their mix design for better quality and improvement in production. The plant has adopted the recommendations, and great improvement has been achieved; another visit was requested during this second mission for more discussions concerning what has been achieved and the possibilities of using low grade limestone.

V RECOMMENDATIONS

1 The recommendations which are given in the first report with regard to the raw materials, raw mix, coal, kiln operation and flammability, fuel and power consumption, clinker quality, dust, pyroprocess, etc., and are shown on pp. 11-14, of that first mission report, apply here.

2 As the raw materials are quite variable, it is recommended that a preblending system should be supplied to the cement plant for smooth operation. Although some of the plants have a preblending system, it is not worked efficiently and its blending factor is low. These limitations should be resolved for better quality control.

3 There are few plants which are producing clinker with about 15% C_3S and 50% C_2S, due to deficiency of CaO content. These plants should practice operating their quarry efficiently and controlling the raw mix before feeding the kiln. In this respect, NCB is capable of advising these plants about the quarry operations and controlling the kiln feed. It is not practical nowadays, to produce cement with low C_3S and high C_2S.

4 R_2O_3 (Al_2O_3 + Fe_2O_3) after the coal ash absorption should be 10% and Al_2O_3 6% maximum in the clinker. A.M. should be in the range of 1.4, in the clinker.

5 It is emphasized here also in this report that coal preferably not have more than 30% ash. It should be blended before feeding the kiln and have about 1% moisture. The burner pipe should be suitable to burn high coal ash. In this respect, it is advisable to the cement plants to seek the advice of NCB who has developed two different types of burner pipe and utilizes the local coal.

6 In the case of using lignite mixed with coal, it is advisable that the moisture content in the fuel should be minimum and a small percent of lignite should be utilized.

7 In the case of dusty clinker, it is recommended to adjust the liquid phase and the clinker granulation. Coal with a high percent of ash has an effect in generating dust in the sintering zone. This subject is discussed later in Chapter VI of this report, titled "Dusty clinker and how to avoid it?"

8 Collected kiln dust can be utilized in the production of masonry cement and in some other applications. Details of dust applications is given under Chapter VI of this report, titled "Kiln dust and its application."

It is advisable to find a more suitable application for the dust than adding it to the kiln feed without controlling its quality and quantity.

9 Maintenance in one of the plants (Dalla Cement) is poor where dust is throughout the plant, E.S.P. and conditioning tower are working on positive pressure, there is leakage from different points in the kiln, etc. This plant needs complete rehabilitation, clean-up, and highly qualified personnel to be keen for cement quality.

10 In the case of using mineralizer to reduce the burning temperature with the objective of saving energy, it is recommended to carry out experiments in the pilot plant of NCB to determine the amount required and the properties of the produced cement. An economic study should be performed. Although one of the cement plants (Orissa Cement) has natural mineralizers (F- and P-components) within its raw materials, yet the presence of these compounds is not taken advantage of as it is burning the feed hard. It is recommended to perform a research study to find the most economic temperature, with the production of high clinker quality and without C_2S conversion. Discussion on mineralizers is given separately in Chapter VI of this report.

11 Free SiO_2 is present in almost all of the raw materials. It reaches to about 90% of the total SiO_2 of the raw mix (i.e., 10% out of 12%). This is considered a very high percent and to compensate its effect, either the raw mix must be ground finer or more iron must be added. In certain cases, both should be adopted and this depends on the particle size of the quartz, the mineralogical composition of the raw materials, the flux, etc. Burnability tests should be done to find the most economic mix characteristics.

In order to acomplish the maximum of the above recommendations, as well as to achieve better quality and maximum operation, it is advisable to the cement plants to ask and seek the advice of the National Council for Cement and Building Materials. This will greatly benefit the plants.

VI ACTIVITIES AND OUTPUT

A. Job description and objective of the second mission activity

The duties of the second mission, as is given in the job description cover beside the entire spectrum of activities relating to raw materials with emphasis on "suitable matching characteristics of various new 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 mineralizers in the manufacture of cement." The purpose of the project is "to improve the industry's productivity and the technological level of the various units of the cement industry in India by strengthening the national center, the National Council for Cement and Building Materials (NCB). The area of approach for this purpose during this mission was:

- the constituents of the raw materials
- mix design and its properties
- preblending system
- coal quality
- coal burner pipe
- fuel consumption
- clinker quality and how to improve it

Besides coal characteristics and its effect on the clinker quality, matching the clinker with the raw mix, flame shape and characteristics, mineralizers, dusty clinker and kiln dust are discussed separately. Each area was analyzed with the interaction of NCB and plant personnel. The production constraints, the bottlenecks and the technical problems were also diagnosed. Recommendations and methods of solving these constraints were discussed for each case and for each plant with the aim of improving the industry's productivity. In the energy field, reduction in heat and power consumption, increasing kiln capacity, and different applications of kiln dust was also discussed during the visit with the plant personnel. The job description of this project follows this page. The personnel of NCB who met during this mission and participated in the discussions are shown in Annex 1.

B. Technical activities

Five different Indian cement plants were visited during this second mission, of which one plant (Madras Cement) was visited during the first mission. Each plant was visited, as in the first mission, for a period of two to three days. A questionnaire regarding raw materials, raw mix, coal, coal ash, clinker, process, operational parameters, fuel and energy consumption and production problems was given to each of the new cement plants visited during this mission. All the departments were visited, from raw materials deposits to

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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

clinker cooler. Intensive discussions with the management and the production personnel took place. Presentation including raw mix design and the parameters and clinker quality by microscope was presented to each plant. A report was prepared for each plant visited, including a short description of the process, observations, production problems. Recommendations with the objective of improving the clinker quality and reducing the production constraints and energy consumptions are given in the report. These are the same recommendations which were discussed with the plant personnel to help them to improve their production quantitatively and qualitatively. The information collected from each plant in the questionnaire is also included in the report. Madras Cement was visited during the first mission where recommendations were given to improve the plant productivity. The recommendations with regard to the raw mix design was implemented, which greatly improved production. The objective of this second visit was to review the achievements obtained and for further discussions.

The reports of the visited plants are attached herewith in Annex 2 - 6 and are as follows:

Annex 2: Report on visiting Orissa Cement

Annex 3: Report on visiting Gujarat Ambuja Cements

Annex 4: Report on visiting Dalla Cement

Annex 5: Report on visiting Rajashree Cement

Annex 6: Report on visiting Madras Cement

The first plant is producing clinker by wet process. The second plant is one of the most modern plants and producing clinker by the precalciner process using 5-stage preheater. The third has two wet kilns and another two dry (SP) kilns. The fourth plant is producing clinker by precalciner technology and using 5-stage preheater. The fifth plant is using an SP system in producing the clinker with firing in the riser duct.

It is also emphasized here that in order to accomplish the maximum production-quality and quantity, it is advisable for these plants to ask for the guidance of the National Council for Cement and Building Materials. Continuous interaction between the 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

Table 1 is a list of the five cement plants visited during the second mission. It also shows the plant locations, process and comments on the raw materials and the utilization factor of the plant. All the plants visited in the second mission, except Dalla Cement, are producing a good quality of cement and the

Table 1: List of plants visited in the second mission

	Name of Plant	Location	Process and Comments
1	Orissa Cement	Rajgangpur, Orissa	Wet process, with production capacity of 1,100 mtpd. Another precalciner system (1,500 mtpd) is under construction. The raw material has P_2C_5 and F-compounds. The production is satisfactory with high utilization factor.
2	Gujarat Ambuja Cement	Keshod, Gujarat	Dry (PC) process with 5-stage preheater, and a precalciner (DOPOL/PREPOL System) with production capacity of 1,700 mtpd. The raw material has low alkali content, thus producing low alkali clinker. The raw mix is characterized by an easy burning raw mix. The production is satisfactory with high utilization factor.
3	UPSCC - Dalla	Dalla, Mirzapur, U.P.	Wet and dry (SP) processes, with production capacity of 3,600 mtpd. Mix design cannot be controlled due to poor quality control. This result is producing variable clinker quality. The plant needs complete rehabilitation.
4	Rajashree Cement	Sedam, Karnataka	Dry (PC) process with 5-stage preheater, with production capacity of 1,750 mtpd. The raw materials contain about 90% free SiO_2 of 12.50% total SiO_2. The production is satisfactory and the utilization factor is 100%.
5	Madras Cement	R R Nagar, Tamil Nadu	Dry (SP) process with firing in the riser duct, with production capacity of 1,600 mtpd. This plant was visited in the first mission. Raw mix has been modified as per the previous recommendations. The quality has been greatly improved.

plants are maintained well. Dalla Cement is in a bad situation with poor clinker quality. Well experienced and qualified personnel are required for this plant, as well as complete rehabilitation and clean-up of the dust and/or the raw mix or dry slurry from all the plant and floors. Continuous advice and guidance from the National Council must be sought, and should be implemented.

The observations and findings of the first mission as shown on pp. 21-31 of the first report are applied here for this report. Besides, these points, the following is added:

1 The constituents of the raw materials: The chemical and mineralogical compositions of the raw materials differ from one plant to another and accordingly the behavior of the raw mix in the rotary kiln. Presence of quartz is most common and it reaches about 90% of the total SiO_2 of the limestone (Rajashree Cement). Low quality of limestone is common except Gujarat Ambuja Cement, where the limestone is high in carbonate content.

2 Mix design and its properties: Mix design of the cement plants visited in the second mission is shown in Table 2, with the mix properties, % of dust and heat, and power consumptions. The plants which are poor in quality control, as Dalla Cement, show many variations in the raw mix. This affects the kiln performance, production (quantitatively and qualitatively) and usually an inferior cement is produced. Gujarat Ambuja and Rajashree Cement have a raw mix with better properties and within a narrower range. They are producing a high clinker quality. Although Rajashree has 10% free SiO_2 in the raw mix, it can be tolerated and a good clinker is obtained. Orissa Cement needs to adjust their raw mix and feed the kiln within a mix of a narrower composition. The recommendation of the different parameters, based on the clinker produced after the ash absorption, is given in the individual report of each plant in the Annex 2-6..

3 Preblending system: Those of the plants which have preblending system unfortunately is not working efficiently. This piece of equipment is essential for the Indian cement plants due to the variation of the raw materials. Measurements and corrections should be done in those plants that have a preblending system that is not working efficiently. The preblending subject is covered in reference 1.

4 Coal quality: Coal used in the four new cement plants visited during the second mission is also variable and has high ash content. Gujarat Ambuja is using coal with 28% ash (30% maximum), which is considered the best of

Table 2: Raw mix properties, % of dust and energy consumption of the plants visited during second mission*

Plant	Orissa Cement	Gujarat Ambuja Cement	UPSCC - Dalla	Rajashree Cement
Raw Mix Composition %				
SiO_2	11.80 - 12.50	12.60	10.50 - 13.50	12.04
Al_2O_3	2.10 - 2.50	3.21	3.00 - 3.70	2.82
Fe_2O_3	1.60 - 2.00	2.54	1.60 - 2.10	2.94
CaO	44.00 - 44.40	44.00	41.50 - 43.50	44.60
MgO	2.90 - 3.40	0.84	2.80 - 3.00	0.40
SO_3	N.A.	0.01	N.A.	0.21
K_2O	0.40 - 0.80	0.16	N.A.	0.16
Na_2O	0.50 - 0.15	0.20	N.A.	0.14
L.O.I.	35.50 - 36.00	35.61	35.50 - 37.00	36.50
Total	-	99.20	-	99.81
S.M.	2.8 - 3.2	2.20	2.10 - 2.50	2.06
A.M.	1.1 - 1.36	1.26	1.70 - 2.00	0.95
H.M.	2.6 - 2.8	2.39	-	2.5
L.S.F.	1.10 - 1.17	1.08	1.00 - 1.25	1.15
Free Silica	3.5 - 4.8	≃3.0	N.A.	10.0
C.C.	75.8 - 76.2	77.0	75 - 78	79.5
M.C.	3.2 - 3.6	1.35	4.5 - 6.0	≃0.8
Fineness +170 mesh	15	15	15 - 18	20
+ 72 mesh	-	1.8	1.0 - 2.2	1.6

Table 2 : Cont.

Plant	Orissa Cement	Gujarat Ambuja Cement	UPSCC - Dalla	Rajashree Cement
% of dust	10 - 14	5 - 10	N.A.	5-7
Heat consumption kcal/kg	1,500	770	950 - 1,050 (Dry) 1,450 - 1,550 (Wet)	830 - 850
Power consumption (kwh/ton	100	120	112 (Wet) 117 (Dry)	135

* Does not include Madras Cement, as this was visited in the first mission.

all the visited plants. Coal consumption also varies according to the process used, but in general, it is low in the case of using coal with low ash content. It is recommended and preferable to use coal with ash content not more than 30% and it should be blended. Coal fineness should be adjusted for better and optimum flame shape and characteristics. Table 3 shows the coal and coal ash properties, fuel consumption and percent of ash absorption of the plants visited during the second mission.

5 Coal burner pipe: The flame of the first, third and fourth plants visited is impingement, long and lazy. The primary air percent cannot be controlled, resulting in high O_2 percent at kiln inlet. Gujarat Ambuja Cement is using a suitable and an updated burner pipe.

6 Fuel consumption: This is considered high for the first and third plants visited. Quality control is very poor in the third plant.

7 Clinker quality: Table 4 shows the chemical analysis of the clinker of all the cement plants visited during this mission. The best is considered Madras Cement and Gujarat Ambuja Cement. Clinker produced from Dalla Cement is considered the worst clinker with C_3S/C_2S : 0.24 - 0.49. It has C_3S between 10-32 and the clinker produced from the wet kiln during the visit was disintegrated as soon as it reached the clinker hall. Clinker produced by Gujarat Ambuja and Rajashree Cement is considered good, but requires a little improvement, as it is stated in Annex 3 and 5, respectively, of this report. Orissa clinker needs to be modified and changed according to the recommendations given in Annex 1. In order to improve the clinker quality of the plants visited during this mission, new parameters were given for each plant (except Madras Cement) in the respective Annex. Clinker of Madras Cement has been greatly improved with better strength, granulatometry and grindability. This was achieved after implementing the recommendations given to the plant during the first visit. This is described in Annex 6 and is verified by XRD which is done by the Madras Cement.

D. Coal characteristics and its effect on the clinker quality

Coal, unlike oil or natural gas, contains considerable quantities of ash and water. The ash and moisture contents of coals from different sources can vary widely, resulting in a widespread of calorific values. Even coal from the same colliery may fluctuate significantly in ash and moisture content and hence in calorific value. Coal is extremely dirty and often contributes a large amount of raw material to the process.

Table 3: Coal and coal ash properties, fuel consumption and % ash absorption of the plants visited during second mission*

Plant	Orissa Cement	Gujarat Ambuja Cement	UPSCC - Dalla	Rajashree Cement
Coal properties:				
Moisture %	2 - 4	1.30	3.0 - 4.7	2.20
Ash content %	28 - 32	28.00	29.0 - 35.5	30-35
H.H.V. kcal/kg	4,800 - 5,200	4,830	N.A.	4,500
L.H.V. kcal/kg	N.A.	4,500	N.A.	4,200
Usable H.V. kcal/kg	N.A.	N.A.	3,900 - 4,500	N.A.
Coal consumption %	29.0 - 32.0	≃17	N.A.	≃ 20.3
% Coal fineness				
170 mesh	15 - 20	12 - 14	14 - 18	10.00
72 mesh	-	-	1.0 - 1.5	0.5
Ash analysis:				
SiO_2 %	56.9 - 59.9	58.90	61.00 - 62.50	58.38
Al_2O_3 %	24.0 - 27.9	22.20	26.00 - 27.00	23.92
Fe_2O_3 %	8.0 - 9.5	6.30	8.50 - 10.50	8.28
CaO %	3.3 - 5.0	-	-	4.83
Other %	1.6 - 2.0	12.60	2.00 - 2.50	4.85
% Ash absorption	6 - 8	5 - 5.5	7 - 10	7

* Does not include Madras Cement as this was visited in the first mission.

Table 4: Clinker analysis of the cement plant visited during second mission (percent by weight - plant analysis)

Constituents %	Orissa Cement	Gujarat Ambuja Cement	UPSCC - Dalla	Rajashree Cement	Madras Cement
SiO_2	21.40 - 22.40	21.35	22.20 - 24.00	22.12	21.20
Al_2O_3	5.00 - 5.30	5.78	6.40 - 7.20	5.20	5.40
Fe_2O_3	2.60 - 3.10	4.24	3.20 - 4.00	4.10	3.70
CaO	63.90 - 64.90	65.42	60.00 - 62.50	65.20	65.8
MgO	4.40 - 4.70	1.50	3.90 - 4.30	0.81	2.00
SO_3	N.A.	0.21	N.A.	0.71	-
K_2O	0.50 - 0.90	0.26	N.A.	0.31	-
Na_2O	0.40 - 0.90	0.30	N.A.	0.21	-
L.O.I.	-	-	0.40 - 1.50	0.34	-
Total	-	99.06	-	99.33	
C.L.W.	1,000 - 1,500	1,220	1,100 - 1,350	1,100 - 1,150	1,200
F.L.	0.80 - 2.50	0.88	1.00 - 2.80	1.2 - 1.30	1.5
S.M.	2.7 - 2.9	2.13	2.00 - 2.40	2.24	2.33
A.M.	1.6 - 2.0	1.36	1.60 - 2.00	1.40	1.46
H.M.	2.0 - 2.2	2.06	N.A.	2.04	2.17
L.S.F.	0.90 - 0.96	0.94	0.79 - 0.84	0.91	0.96
C/S	2.80 - 3.0	3.06	N.A.	2.95	3.10
Potential Composition*					
C_3S	50.0 - 60.0	55.51	10.00 - 32.00	47.6	55
C_2S	20.0 - 32.0	19.04	42.00 - 65.00	27.5	18
C_3A	8.0 - 10.0	8.15	9.50 - 12.70	8.30	8
C_4AF	8.0 - 10.0	12.89	10.00 - 12.00	12.40	12

Table 4 : Cont.

Constituents %	Orissa Cement	Gujarat Ambuja Cement	UPSCC - Dalla	Rajashree Cement	Madras Cement
Liquid Phase	25.77 - 27.28	28.44	30.00 - 33.00**	27.80	28.7
C_3S/C_2S	2.5 - 1.9	'2.92	0.24 - 0.49	1.73	3

* Theoretical calculations based on Bogue formulae.

** Calculated liquid phase by the plant does not agree with the given analysis in the case of UPSCC-Dalla.

Using coal in the cement industry has a major effect on the chemistry of the clinker, as the composition of kiln feed has to be adjusted to accommodate absorption of ash. The ash content of coal exists as both extraneous material and inherent matter. The extraneous material may occur in the seam itself or it may be included from its surroundings. The inherent matter is finely disseminated and interlocked and cannot be separated by physical means, and they therefore fix the minimum ash content. The cement industry in India is burning coal with a wide spectrum of properties. High ash grade coal, new coals with unknown burning characteristics, blends of coal and lignite, etc., are common in the cement plants which demand different burning systems.

Indian coal used in cement production: The Indian cement plants receive coal from more than one source, and accordingly the coal properties are quite different. Ash content available to the cement industry varies from 28 - 42%. The supply of coal to each plant is not homogeneous, as it can be seen from Table 1, page 27, of the first mission report dated December 1986 and from Table 3 of this report. The use of high ash and variable quality coal usually resulted in various pyroprocessing operations and clinker quality problems. This requires continuous adjustment of the composition of the feed, and in most of the plants this cannot be achieved, as the kiln feed already is ground. High ash coal requires the kiln feed to be high in CaO content. The more the ash in the coal, the more Ca is required, which in turn requires high grade of limestone in order for the ash to be absorbed and form the clinker compounds. The amount of high grade limestone is limited.

Coal ash is characterized by high SiO_2 (it varies from 56 - 63%), and Al_2O_3 (it varies from 23 - 28%). Fe_2O_3 in ash varies from 3 - 10%. CaO, K_2O, Na_2O, Cl are also present in the ash, while SO_3 is present in small amounts. Ash absorption varies from 5 - 10%.

Hardness and moisture of the coal are variable affecting coal mill production and the particle size, which accordingly affect the kiln production, flame shape, flame temperature, etc.

Most of the cement plants in India are suffering from the lack of coal quality and they cannot match their kiln feed with the supplied coal. As there is a certain amount of coal ash which can be fused to the clinker particle surface where it reacts with the clinker, therefore, it is preferable that the ash should be limited in the coal to 30% maximum. Using high grade coal or lignite to improve the ash in the coal must be foreseen, if the coal delivered to the plant has more than 30% ash. Burner pipe should be adopted and suitable to burn such a high coal ash. Each plant should exercise grinding the coal to different particle sizes and burn these to select the best fineness which can give optimum flame shape. Blending the coal, which is not a practice in Indian cement plants, must be foreseen and is highly recommended. This will narrow the fluctuations in the coal properties and ash content. Reserve for at least ten days must be available in the plant site.

<u>Effect of coal properties on clinker chemistry</u>: Coal ash causes a significant lowering of the lime saturation factor (L.S.F.) necessitating a kiln feed target L.S.F. considerably higher than that required in the resultant clinker. As a rough guide:

a. Absorption of 1% of a typical ash on the clinker with an SiO_2 content in the region of 50% by the raw feed lowers the L.S.F by about 4%. Such effect will be greater for an ash with a significantly higher SiO_2 content.

b. Coal ash will contribute about 4 - 5% to the clinker, in the case of about 15% is the coal use and with 26 - 29% ash.

c. On dry basis, 1% coal ash causes 1% drop in C_3S, i.e., if 30% ash is in the coal, so C_3S will drop by about 30% in the clinker, over loss free raw meal C_3S projection.

d. Low sulfur coal with about 6% ash reduces L.S.F. from 97 in the raw meal to 95 in the clinker and increases the liquid phase from 27.1% to 27.6% in the clinker.

e. High sulphur coal reduces the L.S.F. from 97 in the raw meal to 86.5% in the clinker. At the same time, the liquid phase is increased to 30% and SO_3 is remarkably increased according to percent of SO_3 in coal and its use percent.

The decreased L.S.F. of the clinker will cause lower initial strength of the cement and an increased SO_3 content, in most cases, will decrease the setting time. The extent of ash absorption is largely governed by the type of process. Careful blending of the coal is highly desirable, especially where ash contents are high. This ensures stable kiln operation and homogeneous clinker quality. During the burning process, ash should be effectively absorbed into the clinker and its quality depends upon this. Failure to effectively absorb ash, especially with high coal ash, can cause heterogenity in the clinker, ard burning, upset kiln operation, ring formation at the preheating zone, etc. Fine grinding of the coal, suitable choice of fuel injection conditions, milling/firing system to be matched to the coal quality, kiln process, raw meal quality are the most important factors in using of high coal ash.

<u>Factors affecting burner performance</u>: For any given coal, the major properties affecting burner performance are fineness, density, moisture, and

volatile contents. The temperature, quantity, velocity, and turbulence of the coal-conveying air are variables of the burner system and should be controlled. Of these variables, the most important is the temperature. The heating rate of the coal is inhibited by low temperature conveying air (primary air). A reasonable time in terms of combustion rate is required to elevate the coal particle to a temperature sufficient to start the ignition process, high temperature supplemental primary air can be introduced with the coal prior to its entering the kiln.

To optimize the burning operation, it is essential to minimize the quantity of coal-conveying air and to maintain direct control over the air/fuel ratio as well as the temperature of the air. The clinker cooler provides the source of high temperature primary air.

The heating value of the coal is an important factor as this determines the amount of coal which must be handled by the system. The ash content affects the clinker chemistry, as it was mentioned earlier, and is also important in determining the wear rate of the mill fan and the mill itself. The variations in ash content affect the amount of alkali contributed to the process, and therefore affect the sulfur to alkali ratio, which is important in case of SP system. High ash content usually reduces the heating value, and this requires a greater quantity of coal. The variations in heating value content of fuel results in an increased need for fuel. This can result in burning zone temperature instability.

The grindability determines the size and power draw of the coal grinding device. The moisture content has a direct influence upon the quantity of primary air and hence the efficiency of the kiln system. The volatility determines the tendency of the coal particles to ignite and this is related to coal grindability. The variation in volatile content affects the sulfur/alkali ratio and burning zone stability. It also affects the operation of a PC system, leading to a flame instability, loss of flame or carryover of incompletely burned carbon to the upper stages of SP system. In general, as the calorific value decreases, the volatility of the coal increases.

Grinding the coal: The coal fineness necessary to produce a suitable flame is given by the following equation (2):

% passing 170 mesh = 100 - (0.5 to 0.7) X % of volatiles. Fine grinding of the coal is necessary to assure complete combustion of the carbon to produce an optimum reaction and to give a short, hot and stable flame. The required fineness of the pulverised coal is dependent upon the volatility content, as coal ignites more readily and rapidly as the volatility increases. A low volatile coal requires more grinding in order to achieve the correct combustion rate characteristics of the coal-air mixture. The temperature of the primary air is also a factor, and is important in preventing premature ignition of the coal-air mixture. Moisture content affects the grindability as well as the burning process.

Coal firing system: There are three standard coal grinding circuit configurations, namely: direct firing system; semi-direct firing system, and indirect firing system.

Indirect system is the most economical system from a fuel point of view, but in practice it requires the most attention and offers the explosion risk. Most of the Indian cement plants visited in the first and the second missions are using indirect firing system. Utilization of an indirect coal firing system improves fuel efficiency of a coal-fired kiln. The utilization of recycled hot air from the cooler will lead to improved flame control and clinker quality, reduced grinding costs and flexibility.

Controlling the combustion process: The modern and the new cement plants visited have the controlling instruments for measuring the oxygen percent, primary and secondary air temperatures, amount of secondary air, temperatures at different levels of the cyclone, etc. The old plants and those which are poorly maintained have no or few instruments for combustion controlling. In this respect, it is recommended that such plants should put all the required instruments in satisfactory operation and maintain the combustion parameters within the given figures of the equipment supplier.

For SP or PC system, the oxygen content in the gas to be maintained at 4.0% at kiln inlet, 2.5% at the fourth cyclone outlet and 3.0% at the induced fan outlet. The 4.0% oxygen at kiln inlet is the optimum value for combustion inside the kiln. The rate of primary combustion air supply is 9% for the kiln and 3% for the calcining furnace, which combined with the entrainment air for fuel transmission, amounts to 14% for kiln and 8% for the precalciner. A representative operating data for a SP and PC system are given in the following table, Table 5.

Table 5: Standard operating data for SP and PC systems

Item	SF	PC
- Fourth cyclone exit gas temperature, °C	870	850
- PC exit gas temperature, °C	865	870
- Induced-draught fan inlet gas temp., °C	365	340
- Preheater exit gas volume, Nm^3/kg-clinker	1.49	1.36
- Power consumption, kwh/kg-clinker	12	9.6
- Kiln exit gas O_2, %	4	4
- Fourth cyclone exit gas O_2, %	3	2.5
- Fourth cyclone exit gas CO, %	0.3	0.07
- First cyclone exit gas O, %	3.5	3.0

Firing a pulverized coal is accompanied by air-conveyed into the furnace. The volatilization system is controlled by rate of temperature rise of the coal particle. Burning the volatile material in the coal involves the following variables:

1 Quantity of primary air
2 Velocity of primary air
3 Temperature of primary air (coal/air mixture)
4 Quality of oxygen in primary air
5 Temperature of the combustion zone into which the coal is discharged
6 Coal characteristics (ultimate and proximate analysis and swelling index)
7 Coal fineness
8 Quantity of inert gases in the primary air (usually water vapor)
9 Relative velocity between the coal particle and the primary air
10 Turbulence between O_2 and fuel
11 Secondary air temperature
12 Secondary air velocity
13 Dust in the combustion zone

All these variables must be controlled. For given coal variations, these factors will influence the ignition rate, flame length, heat release, flame temperature, clinker crystal formation and their sizes, etc. A burner system should have efficient flexibility to vary these factors over a wide range of fuel characteristics. Supplemental primary air of varying temperature and quantity can be used to achieve this.

Coal with high moisture content and/or high ash content: Coal with high moisture content or high ash content or both is characterized by less theoretical adiabatic flame temperature than the conventional fuel. The overall heat consumption (kcal/kg clinker) will be higher than when fired with a conventional fuel alone. Moisture content has a marked effect on coal efficiency and on the unheated air used to inject it. Low grade fuels may have some effect on the clinker output of the rotary kiln system due to limited gas velocity, pressure drop, or induced draft fan capacity. Low grade fuel greatly affects the thermally efficient SP or PC processes more than the less thermally efficient wet and long dry processes, which affect the output, unless this was considered. It is recommended to use a 3-channel burner pipe where the axial and radial air flow can be adjusted.

In this respect, NCB has developed two different burner pipes--stepped and swirl--which are suitable for cement rotary kilns and showed improvement in kiln operation. More intense flame and better visibility in burning zone along with increased production has been obtained (3). It is recommended for the cement plants to use these burners and select the one which gives better flame.

<u>Conclusion</u>: The Indian cement industry must cope with the coal which is used, as it is high in ash content. Coal up to 30% ash can be tolerated and used, but great consideration should be given to the burner pipe, percent of primary air, coal fineness, temperature of air, etc. In the case of higher values of coal ash, coal preparation should be considered. Coal preparation is a mechanical process which benefits coal by sorting to size and/or density to remove the available portion of ash. The preparation techniques include:

1 Processing coal through a rotary breaker with rejection of fines
2 Crushing and sizing coal with a screen and again reject fines
3 Washing coal in a screening plant
4 Using flotation processes to benefit screening
5 Air classifying screenings
6 Any other appropriate processing which eliminates the size fractions which contain the ash

Any of these techniques is costly and will result in wasting a certain amount of the coal (as ash).

Uniformity of coal to the kiln is a process which is missing from all the cement plants which have been visited. Therefore, it is recommended that coal should be crushed and blended in an efficient blending system at the plant site to a size which can eliminate variations within required quantitative values necessary for successful kiln operation. Flame stability is most important to give stable kiln operation and this is achieved by using a homogeneous coal feed stock.

Using a suitable burner for the Indian coal, where the quantity of coal and air flow (axial and radial), must be foreseen in order to control the amount of primary air to obtain a sharp, strong and short flame, as much as possible. Coal should be dried as much as possible and in the case of using lignite mixed with coal, the amount of moisture should be controlled and minimum. It is also advisable and recommended that the raw materials be preblended to ensur~ homogeneous operation and maximum efficiency of the kiln. The subject of preblending the raw materials is given in reference (1) which can also be applied to coal blending.

E. Matching characteristics of various raw materials and fuels

In general, the raw materials used by the cement plants visited are suitable for cement production. In some plants, carefully selecting the raw materials and disregarding certain amount of low limestone are a must. Using high grade limestone as sweetener to increase the Ca content of the mix is highly recommended for some plants. It is necessary that CaO percent of the clinker after the ash absorption should be in 64.5% minimum. Some of the raw materials have natural mineralizers (F- and P-compounds) and others have a small percentage of carbon. Raw materials with high MgO content should be carefully selected, so that the clinker contains less than 5% MgO. All the raw materials of the plants visited contain low SO_3, K_2O, Na_2O and Cl, which is a great advantage. In some cases, low alkali clinker is produced without having an alkali-bypass. The cement produced from such clinker can be sold as low-alkali cement, as in the case of Gujarat Ambuja Cement and Rajashree Cement.

The coal used in cement industry is characterized by high ash (28 - 40%) low in sulfur content and with high heating value less than 5,000 kcal/kg. The coal ash has high SiO_2 and Al_2O_3%. S.M. of the ash is variable and ranges from 2.1 - 2.5. Fe_2O_3 of the ash is also variable and A.M. of the ash ranges from 3.0 - 3.5. SO_3 and alkalies content are low. Some of the coal ash has Cl, and a small part of it is absorbed by the clinker. Absorption of coal ash by the clinker varies from one plant to another. It reaches to 10%, and in some cases is as low as 5%. Those plants which use coal with high ash have encountered many operational problems. As the coal used is variable and not blended, therefore there are many variations in the kiln operation and clinker quality.

Calculating the clinker produced from the loss-free raw mix and the ash used, from the respective percentage, as it is given by each plant, it was found that when the coal ash absorption to the clinker is more than 5 - 6%, the produced clinker does not match with the calculation, in most of the cases.

This can denote that about 5 - 6% of the coal ash can be absorbed by the clinker during the sintering of the raw mix. The excess of the ash is recycled in the system, and can cause operational problems. Therefore, it is advisable that the coal used in the cement industry contain ash in the range of 30%. Blending the coal is very important.

F. Kiln dust and its application

Cement kiln dust is quite variable in chemistry and physical properties. The simple approach to use kiln dust is to be recycled as much as possible. With rising energy and capital costs, recycling kiln dust is an inexpensive way. If the raw feed is low in alkalies, and the low-alkali clinker is required, it is advantageous to utilize the dust in other applications.

The kiln dust produced from the Indian cement plants is usually added to the kiln feed, through the feed pipe going to the kiln without preblending, when the raw mill is down. This results in an erratic and unhomogeneous kiln feed, which affects the kiln operation and clinker quality. In the case, if the mill is working, the dust is added to the mill product, then to the blending system, where it can be homogenized and blended. Consequently, a wide variation in the feed kiln can be observed, when the raw mill is down and when it is operated. Unless the kiln dust is engineered carefully, by having a separate silo where the dust is collected (when the mill is down) and added in specific amounts to the mill product and continuously homogenized in the blending silo, the kiln feed will be erratic in composition.

However, there are different applications for the dust such as:

1 Production of masonry cement: Where certain amounts of kiln dust is ground with limestone and clinker. An air entraining material is added during grinding and such a cement has a high workability and is suitable for masonry works. It cannot be used in reinforced concrete. The presence of air entraining is an advantage to a country like India, where the temperature is high in summer time.

2 Agriculture use of kiln dust: Kiln dust can substitute lime to adjust pH value of the soil. Kiln dust can control pH and also can supply valuable soil nutrients such as potash (K_2O), calcium and sulfur.

3 Kiln dust for environmental improvements: Kiln dust can be used to neutralize acid waste mines, instead of limestome and $Ca(OH)_2$. Kiln dust can stabilize or precipitate heavy metals in sewage treatment or landfill runoff.

4 Flue gas desulfurization: Where slurry kiln dust is pumped and SO_2 is scrubbed from the gas stream.

5 Production of clinker in a fluidized bed: Where small clinker balls act as the seed in the fluidized bed and the kiln dust is reacted on the seed surface and grow in size.

However, the most economic and promised application of kiln dust from the above-mentioned is the production of masonry cement. In this case, if this idea obtained the approval, therefore it is recommended that NCB carry out the required experiment to determine the percent of each component and the properties of the produced masonry cement. A good publicity is required for this cement, its application, its advantage as a masonry material. The user should be aware that its application is limited only to masonry work, and it cannot be used in reinforced concrete.

G. Dusty clinker and how to avoid it?

Clinker porosity and size distribution of the clinker particles leaving the rotary kiln are the quality-efficiency factor of the cement industry. In other words, it can be said that if the granulation of portland cement clinker is poor, it may give rise to problems in the operation of the kiln and cooler.

Dusty clinker is generally well nodulized, but contains a high proportion of the fine unnodulized grains. This creates a dusty condition around the flame and can cause loss of controlling the burning zone. Because dusty clinker is harder to grind, it causes low cement mill production and causes problems in the cooler and its dust collector.

There are some cement plants among those that were visited, that are producing dusty clinker. The most important factors controlling clinker granulation are:

1 The amount of liquid phase present in the clinker and its variation with temperature

2 Particle size distribution and the mineralogy of the kiln feed. If the SiO_2 is present, hence what is its percent and its minimum and maximum size?

3 Percent of minor oxides, such as MgO, K_2O, Na_2O, SO_3, P_2O_3, etc.

4 Feed residence time in the temperature zone in which nodulization takes place.

5 Rate of heating the feed on leaving the calcining zone.

6 Type of pyroprocessing system, kiln slope and round per minute.

7 Diameter of the kiln in relation to fuel consumption rate.

All these factors affect clinker crystal size and its distribution, liquid phase, surface tension and viscosity, and the residence time. The amount of liquid phase is very important, especially at the lower temperature of the nodulization zone. The A.M., MgO content, alkalies, sulfur, P_2O_3, F-compounds greatly influenced the liquid formation.

Particle size of the kiln feed, the heating rate after complete calcination and the amount of calcite and quartz crystals affect the crystal size distribution, the liquid amount and its viscosity during nodulization of the clinker. Slow heating and coarse kiln feed produces coarse belite crystals and free lime, which result in large alite crystals. Raw mixes with high alkalies tend to produce coarse alites.

Well nodulized and easy-grinding clinker is that where there are a large number of small, unconnected pores, while hard-grinding clinker is characterized by fewer and interconnected pores. It is desired that alite and belite crystals be small in size. Such a clinker is well nodulized, easy grinding with small and unconnected pores. Longer crystals tend to produce the latter type.

Dusty clinker consists mainly of large alite crystals which results in poor grindability. Such a clinker produces a system of coarse pores which results in a less grindable clinker, presumably because individual pores provide excellent sites for stress concentration during grinding. Clinker with small pores is ground to a small particle size than clinker with no internal pores, as the latter is much harder to fracture. The raw feed properties (composition and minerology), and calcining and clinkering atmospheres, heating rate, maximum temperature and mechanical factors during burning have much influence on clinker pore size and crystal size. The liquid phase properties such as viscosity and surface tension, at various temperatures and compositions is considered an important factor. In the case of dusty clinker, it is recommended to exercise burning different raw mixes with variable composition and liquid phase until the optimum is obtained. It is usually known that liquid phase of approximately 28% is considered an ideal for granulation and grinding. However, some plants experienced values more than 28% (up to 30%) for better granulation and less dust. Those Indian cement plants which are suffering from dust clinker, it is advisable to analyze these dusty materials to identify this dust, as it can be generated from high coal ash and improper burner-pipe.

H. Mineralizers in cement industry

Certain minor components, including a number of oxides and fluorine-containing compounds can function as fluxes or mineralizers in silicate systems to lower the temperature of melt formation and to accelerate the formation of many compounds which crystallize out of this melt. The temperature of the melt formation can be decreased by the presence of lesser quantities of additional oxides such as MgO, Na_2O, K_2O and SO_3. Compounds such as fluorspar (CaF_2) can further reduce the melt formation and increase the lime assimilation in the formation of calcium silicate, resulting in lower burning temperatures.

Besides CaF_2, there is a widespread, but highly fragmentary, inconsistent, and controversial literature (4, 5) concerning the benefits and/or deleterious effects of complex fluorine compound such as alkali and alkaline earth fluosilicates. Such compounds act as fluxes and mineralizers.

Small addition of certain compounds, such as fluorspar to the cement raw mix facilitates burning and accelerates the silicate formations. List of the different mineralizers/fluxes used in the cement industry and their effects is given in reference (6). In general, the lab experiments showed that raw mixes burned without mineralizer additions were poorly clinkered at 1,300°C and well clinkered at 1,450°C. With mineralizer additions, the raw mix was well reacted at 1,300°C, as free lime, and alite contents are low and high, respectively in comparison to raw mix without mineralizer. Fluxed samples burned at 1,300°C appeared in terms of free lime and alite contents, to be similar to the unfluxed compositions which were burned at 1,450°C. The flux used in the case was CaF_2 and $CaSiF_6.2H_2O$, where the differences were not significant.

In case of using CaF_2 or $CaSiF_6$ as mineralizing agents, there is usually a change in the aluminate phase. The addition of fluorine-containing additives resulted in the formation of $C_{11}A_7$. CaF_2, which gives rise to the peak at 33.4°2Θ and the complete disappearance of the C_3A peak at 33.0°2Θ when examining the clinker by XRD. γ-C_2S (at 29.65° and 32.8°2Θ) can also be formed in case of mixes with a low C_3S/high C_2S content. γ-C_2S causes the appearance of friable clinker due to a β to γ-C_2S polymorphic transformation. This destabilization of β-C_2S appeared to occur in all samples containing CaF_2 or $CaSiF_2$ mineralizer additions, and burned in the lab at 1,300°C. As the clinkering temperature is increased, the ternary compound $C_{11}A_7.CaF_2$ disappears, and C_3A is appeared. The ternary compound generally is formed between 1,290°C and 1,400°C with CaF_2 and an industrial raw meal (7). This is converted to C_3A at temperature above 1,400°C.

The addition of fluorine-containing mineralizers, has an effect on destabilizing the alite. The lab results showed that as the clinkering temperature increased to 1,350°C, there was a slight decrease in free CaO, and a significant increase in C_3S amount. As the temperature was increased by another 50°C increment, the amount of free CaO increased, and there was a simultaneous decrease in the alite content.

It is usually observed that in the raw mix containing fluorine as mineralizers, γ-C_2S is present at 1,300 and 1,350°C, but it disappears at 1,400°C. This suggests that at 1,400°C, C_2S stabilized in β-form. Moore (8) studied the effect of fluxing calcined industrial meals with 1% - 3% additions of CaF_2, and upon rapid cooling of the clinker found no evidence of polymorphic transformation of β to γ-C_2S. The addition of CaF_2 resulted in increased amount of C_3S and also increased the degree of β to γ-C_2S inversion. As the burning temperature was increased to 1,450°C, however, no γ-C_2S was formed upon subsequent cooling.

Effects of mineralizers on clinker compositions: The interaction of fluroide or fluosilicate anions to a cement raw mix results in changes in the phase compositions. It lowers the eutectic temperature and accelerates the chemical reactions resulting in C_3S formation and decreasing free CaO. The presence of mineralizer can change and/or modify the reaction resulting in new compounds, depending upon the initial raw mix composition, the specific mineralizer used, and the burning conditions.

The fluorine ions can enter the crystal lattice of C_3S and change the structure. Clinker compounds containing fluorine show no dramatic losses of strength (9). In all cases, pure C_3S mixes containing greater than 0.5% fluorine were substantially weaker than the corresponding mixes without fluorine. Fluorine increased the early heat liberation, but did not accelerate the early hydration reaction (10).

Potential problems: Presence of CaF_2 in a raw mix may result in certain deleterious effects such as refractory deterioration, kiln ring formation, clinker dusting, coating loss, or low strength in hydrating cement (11,12). It is necessary, therefore, to understand the limitations and possible problems associated with the use of a particular additive to a particular raw mix. It is suggested that each plant is interested to use mineralizer, that NCB should conduct a complete study using the pilot kiln available at the facilities to determine the effective mineralizer and its dosage, quality of clinker and cement, the energy saving and the amount of its use. In the case of Orissa Cement Ltd., where its raw material contains fluorine and P_2O_3, it is highly recommended to have a broad study to investigate the effects of these mineralizers on the burning process and the quality of cement. The limits which should be tolerated without affecting the quality should be determined. In this respect, it is also recommended that P_2O_S and F should be detected for all the nearby existing plants, to determine if these compounds exist in their raw materials or not.

I. Expert appraisal, NCB format

Annex 7 shows the NCB format for expert appraisal for all the cement plants visited during the second mission. These forms were filled and delivered to NCB. They summarize the important aspects covered during the visits and the details are found in the plant visit report.

J. Results of the findings and their utilization

A report is written on each plant visit including the recommendation which should take place by the plant personnel to improve and enhance the plant productivity. The report will be sent to the plant management through the National Council. The recommendations were given based on the data obtained from the plant personnel during the discussion, as well as from the collected data. The recommendations are for short and long terms. The short-term recommendations include immediate action to improve the raw mix design, its burnability, coal quality, kiln operation, etc. Long-term recommendations include selective quarry operation, effective preblending and blending system, blending the coal, and rehabilitation of the plants that are in bad condition, such as Dalla Cement. In the case of Madras Cement, which was visited in the first mission, the plant implemented the recommendations in a satisfactory way and the clinker quality, kiln operation and strength of the cement have been greatly improved. It is expected that the cement plants visited during the first and second missions follow the same implementation as Madras Cement.

K. Raw mix designs and clinker quality

Most of the cement plants visited during this mission are producing a better quality cement, except Dalla Cement. The discussion which was mentioned in the previous report of the first mission pp. 31 - 33 also applies here for the second mission. It is highly recommended for better quality and high strength to keep the produced clinker after the ash absorption within the following range:

S.M.	:	2.4 - 2.6
A.M.	:	1.3 - 1.5
H.M.	:	2.15 (±0.05)
L.S.F.	:	0.94 - 0.96
C/S	:	3.15 (±0.05)
C_3S	:	$\simeq$55
C_2S	:	24
C_3S/C_2S	:	2.3
L.P.	:	28%

Fineness of the raw mix to be around 12% on 170 mesh and 2% on 72%. If the raw mix has high free silica, this can be compensated by grinding the mix finer and/or adding more ir R_2O_3 in the clinker should not increase more than 10% and Al_2O_3 not more than 6%. CaO not less than 64% in the clinker must be foreseen, to obtain high percent of C_3S. Examining the clinker by the microscope technique on a regular basis and by XRD on an irregular basis is recommended, as the Bogue formulae are only theoretical and give the potential and not the accurate figures.

L. Conclusions

Variable raw materials and coal are common in the cement industry in India. Raw materials have quartz and calcite crystals while the coal has high ash content. Selective quarrying and preblending the raw materials and blending the coal, preferably with 30% coal ash, are the requirements for good clinker quality. Limestone as sweetener is required in most of the plants to correct the raw mix and to obtain more C_3S than C_2S. It is recommended to keep the clinker parameters as mentioned above. Detailed studies should be done, before using the mineralizers, to determine the percentage of the most effective material, the sintering temperature, the quality of the clinker and cement followed by an economic study.

Dust collected from some plants is high and corrections should be done to decrease it to about 7% of the kiln feed. Investigation of different applications of the dust must be foreseen instead of adding it to the system without blending, in most of the time. Recommendations presented to each plant after the visit must be implemented to enhance the quality and productivity.

REFERENCES

1 G. R. Gouda and V. Ionita, "Preblending Cement Raw Materials, Why, How and When." Third International Symposium Transport and Handling of Minerals, Vancouver, British Columbia, Canada, 1979.

2 L. Schneider, "Airswept Ball Mills and Roller Mills as Viable Alternatives for Coal Grinding," Presented at Cement Manufacturing Technology, Sept. 10 - 13, 1979. The Pennsylvania State University, University Park, Pa.

3 V. K. Arora, S. N. Yadav and A. Pahuja, "Efficient Use of High Ash Coals - NCB's Approach," An interim report by the National Council for Cement and Building Materials, New Delhi, India, 1985.

4 W. A. Klemm and J. Skalny, "Mineralizers and Flexures in the Clinkering Process," Cement Research Progress, American Ceramic Society, 1976, Chapter 14, pp. 289 - 291.

5 J. A. Imlach, "The Influence of Heating Conditions on the Production of Fluorine-Containing Portland Cement Clinker," Cement Technology, 5(4) 403 - 406 (1974).

6 G. R. Gouda, "Effects of Fluxes on Energy Conservation in Cement Production," Fifteenth International Cement Seminar, Chicago, Ill., U.S.A. (1979).

7 P. Seligmann, "Summary Report on Regulated-Set Cement and Concrete," PCA R/D Ser. 1491-1, Portland Cement Association, pp. 4 - 6, Dec. 1973.

8 R. E. Moore, "Fluorospar Boosts Kiln Efficiency," Rock Products, 63 (12), pp. 108-112 (1960).

9 J. H. Welch and W. Gutt, "The Effect of Minor Components on the Hydraulicity of the Calcium Silicate," Proc. Fourth International Symposium on Chemistry of Cement, Washington, 1960, Vol. I, pp. 59 - 67.

10 T. Sa Kurai, T. Sato and A. Yoshinaga, "The Effect of Minor Components on the Early Hydraulic Activity of the Major Phases of Portland Cement Clinker," Proc. Fifth International Symposium on Chemistry of Cement, Tokyo, 1969, Vol. I, pp. 300 - 321.

11 F. M. Lea, The Chemistry of Cement and Concrete, 3rd Edition, Chemical Publishing Company, New York, 1971.

12 R. M. Bogue, The Chemistry of Portland Cement, 2nd Edition, Reinhold Publishing Corporation, New York, 1955.

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DISCUSSIONS SESSIONS
SECOND MISSION

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2 Mr. D. B. Irani, Director
3 Mr. J. P. Saxena, General Manager
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ORISSA CEMENT LIMITED
RAJGANGPUR, ORISSA

Orissa Cement Limited has two wet kilns producing approximately 1,100 mtpd clinker. A precalciner plant is under construction, with a capacity of 1,500 mtpd, where the raw materials will be ground in a vertical mill.

The limestone used is crystalline with variable percentage of $CaCO_3$. It contains Ca-silicate compounds, pyrites, mg-carbonates and small amounts of phosphates and fluorides. Chlorides, sulphates and sodium are low in the kiln feed, but potassium reaches about 1% K_2O in the slurry. The plant has established a preblending system recently to preblend the limestome but its preblending factor is 1 : 4 maximum.

The wet plant is operating with a utilization factor of 100% and with power consumption of about 100 kwh/t of cement ground at 2,700 cm^2/gm, which are very good figures. Nevertheless, there are some problems with the existing plant operation; which are mainly:

1 High fuel consumption (1,500 kcal/kg clinker), although the raw meal contains natural mineralizers (phosphates and fluorides).

2 Longer initial setting time, which can reach to about 200 min.

3 Dusty clinker; usually in kiln 2.

4 Ball formation and overburned clinker.

As the productions of the wet kilns will be stopped when the dry process starts, hence this report will not cover any observation with regard to the wet production, except:

1 Air to the slurry basin should be regularly operated, without interruption, as this causes sedimentation of the slurry, feeding the kiln with erratic feed resulting in unstable burning process and variable clinker quality.

2 Dust should be added regularly (quantitatively and qualitatively) otherwise disregard it.

3 The plant is not taking advantage of the presence of natural mineralizers in the kiln feed. The burning temperature is high, resulting in overburned clinker and high fuel consumption.

4 Kiln feed should have a narrow deviation in its chemical analysis.

5 Maintenance is considered poor, and should be improved.

This reports covers recommendations for the following:

A Raw materials and raw mix design

B Dry process operation

C Effect of mineralizers on clinker properties

D Economic burning process

A <u>Raw materials and raw mix design</u>

1 The use of a preblending system will help in narrowing the variation of the existing raw materials. The preblending efficiency (1 : 4) is considered low and measurements should be taken to increase it to 1 : 10; approximately.

2 The raw mix which is presently used to feed the wet kiln is considered high in S.M. and A.M. It is highly recommended to adjust the kiln feed so that the produced clinker, after the coal ash absorption, falls within the the following parameters:

S.M.	2.4 - 2.6
A.M.	1.3 - 1.6
H.M.	2.15 ± 0.05
L.S.F.	0.94 - 0.96
C/S	3.15 ± 0.05
C_3S	55
C_2S	25
L.P.	28%
C_3S/C_2S	2.3

It should be noticed that the raw mix of Orissa Cement is considered relatively easy burned mix (without taking in consideration the percent of free SiO_2 and its size). It contains high alkali content and two other materials which are considered as mineralizers (phosphate and fluoride). These should be considered in a way to design an economical mix design, which can be sintered easily to produce a high quality clinker with an economic fuel consumption. In this respect, it is recommended to:

1 Perform burnability tests for several designed mixes (within the above given ranges of the clinker) and select the optimum one.

2 Disregard the siliceous rocks, as much as is possible from the morrum and clay.

3 Increase the iron content in the raw mix.

4 Keep MgO content in the clinker to about 4.5% maximum.

5 Determine P_2O_5 and F contents in the raw mix, which is a must. Determine the maximum percentages which can be tolerated to produce a high quality clinker.

6 Experience burning the raw mix at lower temperature (in the range of 1,350°C) due to the effect of the phosphate and fluoride in the raw mix. Fuel consumption should be decreased accordingly.

B <u>Dry process operation</u>: It is high recommended to start to perform, on a regular basis, the analysis of Cl, F, SO_3, K_2O, Na_2O and P_2O_5 for the raw materials, slurry and the produced clinker of the existing plant. These minor oxides are important and will give a clear picture about the kiln feed and to prevent any future build-up or cyclone plugging. From the available data, it seems that there will be some deficiency in SO_3 content in the system. Adding SO_3 to the feed or using high SO_3 coal will help in decreasing this deficiency; in the case where build-up occurs. Moreover, installing an air bluster and a bypass are a good provision for smooth operation.

The plant personnel should be well trained in dry process production and the problems associated with it.

C <u>Effect of maintenance on clinker properties</u>: CaF_2 is considered as a flux and mineralizer. It lowers the temperature at which liquid is formed, thus reducing the clinkering temperatures, but also increases the reactivity of free CaO with the clinker minerals. CaF_2 causes a decrease in the viscosity of the liquid phase, a reduction of the temperature at which the liquid is formed, and a higher reactivity of the mix components. The introduction of fluoride to a cement raw mix results in the changes in the phase formation and composition. It lowers the eutectic temperature and accelerates the chemical reactions.

It has been suggested that it is likely that:

1 CaF_2 aids in the conversion of C_3A and C_2S mixtures into C_5A_3 and C_3S.

2 Depending on the percent of CaF_2, there are possibilities that $(C_3S)_3.CaF_2$ or $(C_{11}S_4).CaF_2$ can be formed.

3 CaF_2 readily combines with the alumina and ferrite containing liquid phases of portland cement clinker. Fluorides can cause the

decomposition of C_3A into C_5A_3 and CaO, which the latter reacts with C_2S to form more C_3S.

4 $C_3A_3.CaF_2$ can be formed by reaction of CaF_2 with CA. Also $C_{11}A_4.CaF_2$ was detected. At higher temperatures, the fluorine appears to enter the silicate phase rather than being volatilized and form C_3A.

There are many publications on the use of fluorides as a mineralizer and each study shows different results. This depends on the percentage used, the raw materials and the burning process. In this respect, it is advisable to burn the raw mix at different temperatures in the rotary kiln (in the range from 1,300 - 1,450°C) at approximately 50°C intervals. The produced clinker should be evaluated by x-ray diffraction and complete chemical analysis. Also the produced cement should be tested carefully.

The retardation of setting time of the produced cement can be attributed to many factors, such as:

1 Low content of C_3S in the cement will produce low percent of $Ca(OH)_2$ in the paste liquor on hydration and with presence of relatively low quantity of C_3A, will unduly retard the setting or, more accurately, the hardening of the paste.

2 C_3A is not formed, but the dissolution of the silicate shows that C_3A exists. It may be that C_3A is with low reactivity.

3 Formation of any other compound(s) where the fluorine is incorporated, and can retard the setting time.

4 The quantity and quality of gypsum, and its minor constituents.

5 The W/C ratio used, and the room temperature.

6 High alkalies content and low SO_3 which can contribute to incorporation of more alkalies in the crystals of the cement minerals, thus forming solid solutions which can delay the setting time.

Generally fluorides tend to stay in the clinker, partly in the fluro-aluminate phase ($C_{11}A_7.CaF_2$) which is very reactive and can cause "flash setting," which is not a known practice with Orissa Cement, as per their technical personnel.

However, there are some other factors with regard to the mix design, such as:

1 High S.M.

2 High lime content

In order to decrease the setting time (shorter initial setting), besides the above-mentioned experiment to sinter the raw mix at different temperatures to identify the raw mix composition and burning conditions of the clinker which gives lower initial setting time, it is suggested to add small amounts of gypsum to the raw materials or use high S coal in order that the produced clinker contains about 0.60% SO_3. This will enable combination of SO_3 with K_2O and some of free CaO to form : 2 $CaSO_4.K_2SO_4$ which is known as langbeinite. When calcium langbeinite is hydrated, it forms syngenite ($CaSO_4.K_2SO_4.H_2O$) and gypsum as hydration products. Syngenite in cement causes severe pack set problems. Therefore, it is recommended that small amounts of gypsum be added to the raw materials. An experiment can be carried out by burning such as slurry in one of the existing kiln and then evaluate the produced cement. Increasing Al_2O_3 in the raw mix (max. 5.8% in the clinker) can produce high C_3A, which will hasten the setting time. Also adjust the raw mix to obtain more C_3S and in this respect use the microscope technique to evaluate quality and quantity of C_3S crystals.

It is also recommended to study the hydrated cement which is now produced by XRD to investigate if ettringite is formed or not.

It is usually known that Bogue formulae are only indication of the potential composition. They do not reflect the actual mineral composition of the produced clinker, as there are several factors that affect the percent of each mineral. It is usually experienced that C_3S percent is higher than the calculated formula, as is detected by XRD and microscopic examination, while C_2S is decreased. Also, the use of CaF_2 appeared to result in higher C_3S (which is not taken in consideration in the Bogue Formula). In this case and at higher temperatures, there is a possibility that C_3S is decomposed with an increase of free lime.

It is recommended that a broad study be carried out by using XRD, DTA, TGA, etc., to evaluate the raw materials, raw mix(es), clinker and cement to get the optimum parameters. It is advantageous that the raw materials have natural fluxes (phosphate and fluoride), so maximum benefits in reducing the cost (especially in fuel consumption) and obtaining a high quality should be achieved.

D Economic burning process: Raw materials with fluorine--containing mineralizers--can lower the clinker temperature, either broaden or narrow the sintering range, and change the viscosity and the amount of the liquid phase. It has been reported that use of higher burning temperature for raw materials containing CaF_2 (as it is practiced in most cases by Orissa Cement) can cause formation of large clinker balls and a sticky clinker—adding to this high MgO content. With proper temperature control, fineness of the raw mix and flame shape, clinker stickiness can be controlled.

The presence of CaF_2 in a raw mix can result in some deleterious effects, such as refractory deterioration, clinker dusting (besides high S.M.), coating loss, clinker ring formation and inconsistent strength. Therefore, it is necessary to limit the percent of F which can be tolerated. It is advantageous that Orissa Cement has a wet process plant and a research institute, so it can perform the experiments and tests required. This will help for smooth operation for the dry process.

Conclusion and Recommendations: The presence of phosphate and fluoride are considered an advantage as they are mineralizers in clinker production. Orissa Cement is not taking advantage of these, as fuel consumption is very high. The raw mix is high in S.M. and A.M. and about 3.0% MgO. Dusting, balling, overburning, instability of coating, longer initial setting time are the problems encountered with Orissa Cement. It is requested to lower the S.M., and A.M. and keep the liquid phase in the range of 28%. Homogeneous feed is emphasized and is better to disregard adding the dust to the slurry (investigate other application for dust use). The sintering temperature is high and it is recommended to have a research program to determine the maximum burning temperature and the corresponding cement quality. Tricalcium aluminate is formed in the clinker, as it is shown by XRD after removal of the silicate. In order to investigate the reason for longer setting time, it is recommended to study the quality of the gypsum added to the clinker in the cement mill, W/C ratio, etc. Also, it may be grinding gypsum with the raw materials will help in decreasing the setting time.

Preblending of coal must be foreseen and great attention must be paid to the plant maintenance. Determinations of all the minor constituents on a regular basis for the raw materials, slurry, clinker, coal ash must be performed. This is very important for the dry process operation.

ORISSA CEMENT LIMITED

Information Collected

Raw materials: Limestone, clay, and morrum are the raw materials used to produce cement by Orissa Cement Limited. The limestone is a crystalline metamorphosed deposit. Four different quarries are in operation, of which quarries 1, 2, and 3 are considered homogeneous, high in carbonate and also high in Mg-content. Quarry 4 is heterogeneous, low in carbonate and high in Mg-content and alkalies in comparison with the other three quarries. Viens of calcite are commonly distributed besides quartz. They are in the rate of 3 mm - 0.2 mm and 0.1 - 0.2 mm, respectively. The properties and chemical analysis of the raw materials are as follows:

	Limestone	Clay	Morrum
Property	Crystalline	Plastic	Plastic
Moisture	0.5 - 1.0	10 - 20	8 - 15
SiO_2	9.00 - 12.00	60.50 - 66.50	35.50 - 48.60
Al_2O_3	1.40 - 2.50	11.90 - 13.80	9.00 - 15.00
Fe_2O_3	0.80 - 1.20	8.30 - 10.50	24.80 - 34.00
CaO	45.30 - 46.50	2.00 - 2.50	1.00 - 3.00
MgO	2.70 - 3.60	0.50 - 1.70	1.00 - 2.10
SO_3	N.A.	N.A.	N.A.
K_2O	0.15 - 1.50	0.44 - 1.00	0.13 - 0.31
Na_2O	0.04 - 0.10	0.04 - 0.26	0.04 - 0.08
L.O.I.	36.40 - 38.20	7.00 - 12.50	8.10 - 11.80
Free SiO_2	3 - 4	N.A.	N.A.
Cl	N.A.	N.A.	N.A.
Total Alkalies	0.14 - 1.09	0.33 - 0.92	0.13 - 0.28

Mineralogically the limestone consists mainly of calcite and quartz, sericite and phlogopite as minor constituents. The limestone contains fluorides from the phlogopite (up to 0.25% F) and also phosphates.

Raw mix: Slurry with 29 - 30% moisture content and 95.2 : 3.9 : 0.9 limestone, clay and morrum; respectively.

SiO_2	11.80 - 12.50		
Al_2O_3	2.10 - 2.50	S.M.	2.8 - 3.2
Fe_2O_3	1.60 - 2.00	A.M.	1.1 - 1.36
CaO	44.00 - 44.40	H.M.	2.6 - 2.8
MgO	2.90 - 3.40	L.S.F.	1.10 - 1.17
SO_3	N.A.	C/S	3.4 - 3.7
K_2O	0.40 - 0.80		
Na_2O	0.05 - 0.15		

L.O.I.	35.50 - 36.00
Free SiO_2	3.50 - 4.80 (7 - 8% was also reported)
Fineness	15% on 170 mesh (mostly calcite)
Total Alkalies	0.40 - 0.70
$CaCO_3$	75.8 - 76.2
$MgCO_3$	3.2 - 3.6

<u>Clinker:</u>

SiO_2	21.40 - 22.40
Al_2O_3	5.00 - 5.30
Fe_2O_3	2.60 - 3.10
CaO	63.90 - 64.90
MgO	4.40 - 4.70
SO_3	N.A.
K_2O	0.50 - 0.90
Na_2O	0.10 - 0.22
Total Alkalies	0.40 - 0.81
C.L.W.	1,000 - 1,500 gm/litre
F.L.	0.80 - 2.50
S.M.	2.7 - 2.9
A.M.	1.6 - 2.0
H.M.	2.0 - 2.2
L.S.F.	0.90 - 0.96
C/S	2.8 - 3.0
C_3S	50.0 - 60.0
C_2S	20.0 - 32.0
C_3A	8.0 - 10.0
C_4AF	8.0 - 10.0
L.P.	-

<u>Plant process and capacity</u>: Orissa Cement Limited started production in 1951 by a kiln producing 500 mtpd. Later on, another kiln was added to produce 600 mtpd. Both kilns are using the wet process and were supplied by F. L. Smidth. Five hundred sixty-one and 672 mtpd can be obtained from both kilns, respectively; and have a utilization factor 100%. The first kiln is supplied with planetory cooler while the second with a grate cooler. Two slurry mills are used to produce 60 - 65 mtph each, with power consumption of 15 kwh/t. A precalciner plant (1,500 mtpd) is under construction now by KHD.

Fuel: Coal with analysis

C	42 - 49
H	2.4 - 3.2
H_2O	2 - 4
Ash	28 - 32
H.H.V.	4,800 - 5,200 kcal/kg

Firing system: Indirect, with particle size of 15 - 20% residue on 170 mesh.

% of primary air: 25%

% of ash contribution: 6 - 8% to the clinker

Ash analysis:

SiO_2	56.9 - 59.9
Al_2O_3	24.0 - 27.9
Fe_2O_3	8.0 - 9.5
CaO	3.3 - 5.0
MgO	1.6 - 2.0

Fuel consumption: In the range of 1,500 kcal/kg clinker (29.0 - 32.0%).

Lifetime of bricks: 4 - 6 months

Thickness of kiln coating: 6" - 10"

Percent of dust: Varies from 10 - 14% and the dust is added after mixing it with water to the slurry.

Burning temperature: Approximately 1,500 °C

Back end temperature: 150 - 160°C

Type of dust collector: ESP

Kwh/ton of cement: 100 kwh/t of cement for OPC ground at 2,700 cm^2/gm.

Plant problems:

1 Longer initial setting time

2 Clinker dusting

3 Ball formation and overburned clinker

ORISSA CEMENT LIMITED
RAJGANGPUR, ORISSA

Names of persons who participated in discussions from Orissa Cement Limited.

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4	Mr. S. Chatterjee	Asst. Lab. Manager, OCL
5	Mr. R. R. Dalmia	Asst. Prod. Supdt., OCL
6	Mr. R. C. Gupta	Asst. Lab. I/C, OCL
7	Mr. R. N. Mahapatra	Asst. Engineer, OCL
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10	Mr. G. K. Verma	Sr. Asst. Mines Supdt. -do-
11	Mr. K. B. Sengupta	Sr. Geologist, OCL

Names of NCB Counterparts.

1	Dr. (Miss) K. Raina	Scientist
2	Dr. M. M. Ali	Scientist

GUJARAT AMBUJA CEMENTS LIMITED
KODINAR, DIST. AMRELI, GUJARAT

Gujaret Ambuja Cements Limited is considered one of the newest cement plants operated today in India. It is operated with a 5-stage preheater and a precalciner. The equipment is supplied by Krupp Polyisus, West Germany; using DOPOL/PREPOL system. The production capacity of the kiln is 2,400 mtpd, but 2,700 mtpd can be achieved.

The plant was just commissioned about five months ago and all the equipment is working with great satisfaction using the most modern and highest technology in cement production. The process—material and heat—is controlled using a closed circuit process control for the raw mill, kiln and cooler, coal mill and cement mill. The plant is operated by qualified personnel.

The limestone—main component of raw materials—and the marl are considered pure materials with very low percentage of minor constituents (sulphate, alkalies, chloride). A very small amount of phosphate is found with the raw materials. Sandstone with about 3% is added to the limestone and marl to increase the SiO_2 content. The raw mix is considered an easy-burning mix, producing a high quality of homogeneous, non-dusty and of about one inch clinker balls. The fuel consumption is less than 800 kcal/kg clinker. All the information collected is attached herewith.

Plant problems: Practically, it can be said that the plant has no problems with the raw material deposits, raw mix burnability, clinker quality and production capacity. The difficulties which are encountered with Gujarat Ambuja Cements Limited are mainly associated with:

1 The raw materials handling, due to the stickiness of the marl and the low hardness of the limestome. Marl and limestone are crushed to produce a closer raw mix composition. Finer adjustments take place by the bins ahead of the roller mill.

2 Flame shape and its affect on bricks lifetime.

Materials handling: In this respect, it is recommended:

1 The crushed limestome and marl should be coarser. The impactors of the crusher should be readjusted to produce mostly coarser products. The roller mill can handle 75mm size stone easily. Using a ripper for the limestone is less costly than using explosives, but maybe more fines will be produced. The limestone is coral in its formation and easily fragmented.

2 Adding a small percentage of sandstone to the raw materials to be crushed in the crusher can help in decreasing the amount of fine, and increase the crusher production.

3 Having a low and high raw mix composition, could be handled easier. In this case, low mix can bypass the crusher. A study for this idea will show its feasibility.

4 Stacker requires some modification. The variation of its performance between day and night should be overcome.

5 To have air blasters nearer to the discharge openings of the raw materials hoppers.

6 To cover the belt conveyors of the raw materials and add a dust collector. Spraying a little amount of drinkable water will decrease the dust.

Flame shapes and its affect on bricks lifetime: The plant is firing the coal without 28% ash using Pillard burner pipe, which is considered the most efficient one. It is recommended that:

1 The flame sould be intense, sharp, and slightly directed to the kiln feed. Trials to be performed to optimize coal particle size.

2 Avoid wide and impingment flame.

3 Primary air should be exactly measured and the amount of oxygen controlled at the different points, as per the supplier's instructions.

4 Use homogeneous coal with optimum particle size and minimum moisture content.

5 Coating should be--more or less-evenly distributed through the burning zone, with a reasonable thickness.

6 Burner pipe should be moved in and out constantly, to evenly distribute the coating.

7 In the case of small thickness of the coating over the bricks, increase the liquid phase (especially the iron content) in the raw mix for a few days. The liquid phase which is currently in the clinker (28%) is an ideal one of clinker grinding and may not be sufficient to form a relatively thick coating.

General recommendations:

1 In order to avoid cement expansion, it is recommended to increase the S.M. to the range of 2.3 - 2.4; while keeping the A.M. about 1.36. Avoid increasing R_2O_3 more than 10% and Al_2O_3 more than 6%.

2 Keep H.M. 2.15 (±0.02), C/S : 3.10 ± 0.05 and L.S.F. 0.94 – 0.95. Liquid phase in the range of 28% is a good figure. C_3S and C_2S according to Bogue calculations should be in the range of 55 and 22, respectively keep C_3S/C_2S in the range of 2.5.

3 The raw materials used have low impurities which is a big advantage, as the clinker which is produced is characterized by low alkali contents. In this case, the cement can be sold as low alkali cement which is required to avoid alkali aggregate reaction and for long durability. Performing alkalies (Na_2O and K_2O) should be carried daily and perhaps on each shift, in the case of marketing the cement as low alkali. Testing at outside organizations, to confirm the results, is of great advantage.

4 Minor constituents (SO_3, Cl, K_2O, Na_2O, P_2O_5) should be determined on regular basis for the raw materials, kiln feed, clinker, cement, coal, coal ash, kiln dust, where it is applicable.

5 It is advisable to control the CaO content of the kiln feed by using an x-ray fluorescence rather than the acid-alkali method. CaO content of kiln feed should be kept in the range of ±0.1% for smooth kiln operation, and homogeneous clinker quality.

6 Preblending the coal must be foreseen for maximum efficiency of the pyroprocessing process.

7 Covering the storage areas and top of cyclone I is recommended to counter-effect the monsoon season for continuous operation.

8 The collecting devices of the I.D. fan bag-house should be revised to be able to accommodate all the collected dust.

9 It is a great advantage to convert the existing open-circuit cement mill to closed circuit, as present power consumption (48 kwh/t cement) is very high. This will save quite a few kwh/t cement and increase the mill production, as well as the strength could be improved.

10 It is highly recommended to apply the microscope to the clinker quality to determine the optimum strength with regard to the crystals quantity and size, clinker grindability, raw mix design, flame shape, burning temperature, etc.

11 The raw mix is considered an easy burning mix, it is recommended to lower the burning temperature to about 1,350°C. This will slightly increase the free lime in the clinker, and lower the clinker litre weight. It is expected a stable coating in th ln and an easy grinding clinker.

GUJARAT AMBUJA CEMENTS LIMITED
KODINAR, DIST. AMRELI, GUJARAT

Information Collected

Raw materials: The main raw materials are limestone and marl, which exist in the same deposit; are about 2 km from the plant. The thickness of the limestone beds is about 10 meters, and is followed by the marl. Sandstone is added as a corrective material for SiO_2. These raw materials have the following properties and analysis:

Properties	Limestone	Marl	Sandstone
Plasticity	Non-Plastic-Coral	Moderate	Non-Plastic
Hardness	3	6	7
Moisture %	4 - 6	7 - 10	3 - 4
SiO_2	5.90	32.38	92.98
Al_2O_3	1.86	8.33	2.83
Fe_2O_3	1.39	9.26	0.35
CaO	49.69	23.38	1.30
MgO	0.64	2.86	0.10
SO_3	0.01	0.02	0.05
K_2O	0.16	0.30	0.23
Na_2O	0.11	0.40	0.03
L.O.I.	40.07	23.07	1.22
Total :	99.90	100.0	99.09
Free SiO_2	2.50	7.00	90.00
Cl	0.008	0.006	0.005
Total Alkalies	0.21	0.60	0.18
P_2O_5	0.10	-	-

The limestone is considered a high grade deposit. It contains about 90% $CaCO_3$, with negligible amounts of impurities (minor oxides).

Mineralogically, it is mainly calcite (90%) with some other different minerals forming 10%. Due to the purity of limestone and low SiO_2 of the marl, sandstone is added to increase SiO_2.

Raw mix and its chemical analysis:

Raw mix components:	Limestone	Marl	Sandstone
	81.3%	15.3%	3.0%

It has the following chemical analysis:

SiO_2	12.60
Al_2O_3	3.21

Fe_2O_3	2.54		
CaO	44.00	S.M.	2.20
MgO	0.84	A.M.	1.26
SO_3	0.01	H.M.	2.39
K_2O	0.16	L.S.F.	108.00%
Na_2O	0.20	C/S	3.68
L.O.I.	35.61		
Total :	99.20		

The raw mix has 77.0% $CaCO_3$, 1.35% $MgCO_3$ and 0.008% Cl. It is ground up to 15.0% residue on 170 mesh and 1.8% residue on 72 mesh.

Clinker:

SiO_2	21.35				
Al_2O_3	5.78				
Fe_2O_3	4.24	S.M.	2.13	C_3S	55.51
CaO	65.42	A.M.	1.36	C_2S	19.04
MgO	1.50	H.M.	2.06	C_3A	8.15
SO_3	0.21	L.S.F.	0.94	C_4AF	12.89
K_2O	0.26	C/S	3.06	L.P.	28.44%
Na_2O	0.30				
L.O.I.	-				
Total	99.06				
F.L.	0.88				
C.L.W.	1,220				

Plant capacity: It is 2,400 mtpd (designed), but 2,700 mtpd has been obtained. The utilization factor of the plant is approximately 110%.

Process: It is dry process, using DOPOL/PREPOL system supplied by Krupp Polysius. It is a 5-stage preheater and a precalciner with a rotary kiln of 4 mt. diameter (inside shell) and 60 mt. length. The kiln is not provided with a bypass and clinker cooling takes place in a grate cooler. The fuel is splitted 60 : 40, precalciner : kiln with a calcination of 90% in the precalciner and in most of the cases less than 0.1% CO at the PC exit.

Fuel: Bituminous coal with:

C	51.5
H	3.8
N	1.20
O	4.80
H_2O	1.30

Ash	28.00
H.H.V.	4,830 kcal/kg
L.H.V.	4,500 kcal/kg

Firing system: Indirect using Pillard burner

Particle size of coal: 12 - 14% residue on 170 mesh

% of air: Primary 12%

% ash absorption: 5.0 - 5.5%

Ash analysis:

SiO_2	58.90
Al_2O_3	22.20
Fe_2O_3	6.30
SO_3	3.20
Others	9.40

Fuel consumption: 770 kcal/kg clinker

Lifetime of bricks: 60 - 75 days—using 70% Al_2O_3 refractory

Thickness of kiln coating: 200 mm and is unstable

% of dust: 5 - 10%

Burning temperature: 1,400°C

Back-end temperature: 1,050°C

I.D. fan temperature: 320°C

Type of dust collector: Glass bag-house

Is dust usable: Yes—with the mill product when the mill is working and back to the silo when the mill is not working.

Clinker size: Min. -1 mm and max. 30 mm

Total kwh/t cement: 120 kwh/t cement at 3,300cm^2/gm; using open circuit mill.

Breakdown of kwh/t:

Crusher	3.0	
Raw mill	21.0	(including preblending and blending)
Kiln	41.0	
Cement mill	48.0	
Packing house	4.5	
Misc.	2.5	
	120.0	

Technical problems:

1 Raw materials handling

2 Lifetime of bricks

3 Further improvement in compressive strength of the cement.

GUJARAT ABMUJA CEMENT LIMITED
KODINAR, DIST. AMRELI, GUJARAT

Names of persons who participated in discussions from Gujarat Ambuja Cement Limited.

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3	Mr. V. V. Karambelkar	Sr. Mgr. (Elec.)
4	Mr. G. D. Bhosle	Sr. Mgr. (Engg.)
5	Mr. B. I. Dulani	Sr. Mgr. (Prod.)
6	Mr. M. L. Chamoli	Manager (Prod.)
7.	Dr. Y. Z. Pathak	Asst. Manager (Process)

Names of NCB Counterparts.

1	Mr. A. D. Agnihoteri	Scientist
2	Mr. T. N. Verma	Scientist

DALLA CEMENT, UPSCC
MIRZAPUR

This plant was started in 1971 by two wet rotary kilns, each producing 600 mtpd. In 1982 another two kilns were added, working by dry process (SP system), each designed to produce 1,200 mtpd. The obtained capacity for the wet kiln is around 630 mtpd and for the dry kiln is around 1,000 mtpd. The information collected from the plant is attached herewith.

The raw materials are about 2 km from the plant, where the limestone deposits are. They are mixed with clay and shale (about 7%) in different proportions. The limestone is a mixture of calcareous and dolomitic stone with nine different beds where six beds are only utilized at present. Calcium carbonate ranges from 75 - 76%, whereas magnesium oxide is about 2% in the beds from 1 5, while bed 6 has 3% MgO. The crushers are located in the quarry and the crushed limestone after "preblended" is transported to the plant by a ropeway. The crusher of the first plant is single closed circuit hammer crusher with a sieve, while the extension has two crushers; primary and secondary. The primary is gyrotory and the secondary is two hammer crusher (from two different suppliers). A sieve for clay and shale separation is established between the first and secondary crusher, where the sieved limestone reaches to about 80% calcium carbonate. White marble (85% $CaCO_3$) is used as sweetener.

The crushed limestone is preblended in a circular stacker reclaimer, where the stacker is not working due to malfunction of its radial shaft.

Although the wet and dry processes are about 15 and six years old, yet there are several problems and production bottlenecks for both the processes. The plant needs complete clean-up and rehabilitation. The plant is working with less than 50% of control instruments. Understanding the basic of quality control in cement industry, maintenance of the equipment, reducing the dust emission, continuous checking of the calcium content in the raw mill and kiln feed, adjusting the feed, etc., are weak and loose with minimum (or perhaps none) supervision. During the visit, it was noticed that the clinker producing from the wet kiln is disintegrated to powder just when it reaches the clinker yard. The total carbonate during this period (from 7:00 a.m. to 5:00 p.m.) was less than 75.00%, and no action was taken to correct the kiln feed. As it was informed from the production manager, there is no manpower for hourly checking the carbonate of the kiln feed, as well as no chemicals for testing the clinker for free lime. However, the following are the recommendations:

Raw materials:

1 To improve the quality of the limestone, more clay and shale are required to be removed by increasing the sieve opening.

2 Ropeway for handling the crushed limestone is a big bottleneck, another method should be evaluated.

3 Raw materials should be controlled from the quarry, by determining the carbonate content of the beds, crushed and stacking materials and adding the required amount of high grade limestone.

4 Circular stacking reclaimer is inefficient in stacking, it should be operated satisfactorily.

5 Experiments should be done to improve the efficiency of blasting, by using different explosives, pattern, depth, diameter, etc.

6 Quarry equipment should be reviewed. It seems that more equipment is required.

7 MgO content in the clinker should be controlled from the deposits. It is advisable to be less than 5% in the produced clinker.

8 In the case of using marble as a sweetener, its percent should be determined and its affect on burnability, clinker quality, kiln performance and production. It seems that, no one now knows what is the percent used and the effect of this amount on burnability.

9 Sweetener should be stacked in the plant, with an amount sufficient for at least a week. Its percentage should be added exactly through an accurate weight feeder.

10 Dust from wet and dry process is transported to the limestone stack yard. Application of the dust should be engineered carefully and it is preferable to be added to the blending silo of the dry process, through accurate measurements with the raw mill product. Transported the dust and mixing it with the limestone, beside increasing the cost; will generate some problems in dry mill grinding.

Wet plant: A complete rehabilitation, maintenance, new control instruments, repair the equipment which are out of order, cleaning, etc., are required. It is recommended.

1 The feed table of the raw mills to be used for controlling the amount of the feed to the mill. Sweetener to be added with controlling the amount. No control for the feed and there is only one component, as whatever comes from the quarry is ground. Quality control is very poor and reluctant.

2 Two slurry silos out of the six are not operated for a long time. The plant was supplied by six slurry silos for better operation and controlling the kiln feed.

3 Only one meter out of the six meters of the slurry basin depth is approximately the effective depth for kiln feed. Automatic rotation is out of order. It is highly recommended to clean all the depth of the slurry basin.

4 During the visit, only one kiln was operated and the flame was long, lazy with long glome. Leakage is high through all the pyroprocessing system from different places. Control instruments are not working. Amount of coal to kiln is uncontrolled and has high moisture. Primary air, amount of O_2 at kiln inlet, etc., can not be measured. Kiln coating is weak and fuel consumption is high (1,450 - 1,550 kcal/kg clinker). The kiln is running without chains. No continuous checking for the carbonate of the kiln feed. It is impossible to run a kiln with these conditions and to obtain a good clinker quality. It is highly recommended that direct actions should be taken to correct these abnormalities and weak supervision. Large sizes of "clinker" balls, which is grey in color from the outside (about 2 mm thickness) and the inside is calcined slurry, was noticed during the visit.

Dry plant:

1 There is no control to the amount of the raw materials as it is only one mix component. Whatever material, which is usually one component, comes from the quarry is ground without correction. The weight feeder is not steady and is changable every 2 - 3 days (as per the production manager).

2 Raw mill is double rotator with less production than the designed. Tests to be done to change the amount of feed to each compartment and to check or change the ball charge.

3 Fineness (14 - 17%) is considered high, with regard to the present raw mix composition; free lime is not determined, autoclave expansion (sometimes) out of specification. Measurements should be taken to correct the mix as it will be stated later.

4 Blending silos are working with low compressed air, resulting in uncompletely homogenized kiln feed.

5 High amount of leakage at several points in the pyroprocessing system. Kiln draft is low, a space of about 10 cm around the burner pipe, door of the kiln hood is closed about 2/3, temperatures cannot be measured, oxygen at kiln inlet is 4 - 6%, and at the preheater fan is 16%. P

across the preheater is low, C.T. and E.S.P. are working under positive pressure, thin coating inside the kiln and lifetime of bricks is low, variable kiln feed, fuel consumption 950 - 1,050 kcal/kg, etc., are some observations. It is highly foreseen to put all the pyroprocessing in right operation.

Raw Mix: The raw mix which is burned now either in wet or dry process produces clinker which is characterized by deficiency in CaO, high SiO_2, unbalanced, with Al_2O_3 over 7%. It is not well homogenized and inconsistent. XRD showed that the produced clinker has high amount of C_2S, low C_3S, high C_3A, and contains free SiO_2 and lime and MgO. Coal with about 38% ash is used, resulting in high ash circulation, poor clinker quality, and ash absorption varies from 7 - 10%. In this respect, it is recommended that:

1 To have a raw mix such that when it is burned, will produce clinker, after the ash absorption; within the following limits:

S.M.	2.4 - 2.6
A.M.	1.38
H.M.	2.15± 0.05
L.S.F.	94 - 96%
C_3S	55
C_2S	25
L.P.	28%
C_3S/C_2S	2.3

The Al_2O_3 should not exceed in the clinker more than 5.8% and the coal preferably not contain more than 30% ash. Optimum coal particle size and burner pipe which gives an intense, short and sharp flame should be utilized.

2 Free lime in the clinker should not exceed more than 1.2% for OPC.

3 Produced clinker should be tested by microscope techniques to optimize the quality and the burning process.

4 Free SiO_2 and the minor oxides should be determined for all the used and produced materials, where it is applicable.

5 Burnability tests to be carried out to determine the percent of sweetener to be added and the required particle size.

Quality control and lab: The quality control is poor, the lab is not organized and several tests are not performed. In this respect, it is recommended that:

1 Kiln feed, either wet or dry, should be tested on a regular basis, every hour, beside mill product.

2 Sampling should not be "grapping," but it should be a representative one.

3 Use XRF to determine calcium content, rather than using the titration method.

4 Lab equipment should be updated and the personnel to be upgraded and keep up-to-date with the technology change.

5 Representative average clinker samples from each kiln to be analyzed daily separately. Free lime to be done for average sample/shift/each kiln until stability and good quality is obtained, then daily for an average sample for each kiln.

6 Coal should be blended in an efficient blending system before grinding it, and with 30% maximum ash. Moisture in the coal to be around 1%.

7 Control instruments should be put in operation including recorders, and stop the leakage from all the points.

Notes:

1 Dalla Cement is considered in a bad situation. Complete rehabilitation and shake-up should be considered to return its operation as a normal cement plant.

2 A short visit was completed to Churk Cement Plant which is another plant associated to UPSCC (U.P. State Cement Corporation). Credits should be given to the plant personnel for keeping it very clean and in good operation. Also, to their awareness of the quality. Some modification to the mix design and burning shape are required for the Churk Plant. Recommendations were discussed and explained.

DALLA CEMENT, UPSCC
MIRZAPUR

Information Collected

Raw materials:

1 Limestone deposits mixed with clay and shale in different proportions, affecting carbonate content.

2 Marble with some quartz crystals.

3 Blue dust as a supplier for iron ore.

The chemical analysis of these raw materials, are as follows:

	Limestone	Marble	Blue Dust
SiO_2	11.00 - 13.50	9.00 - 19.20	3.50 - 4.26
Al_2O_3	3.00 - 3.70	Nil - 1.80	4.00 - 4.30
Fe_2O_3	1.40 - 1.55	1.00 - 1.55	89.00 - 90.50
CaO	41.80 - 43.70	41.20 - 47.00	Traces
MgO	2.80 - 3.20	2.10 - 2.60	Nil
SO_3	N.D.	N.D.	N.D.
K_2O	N.D.	N.D.	N.D.
Na_2O	N.D.	N.D.	N.D.
L.O.I.	35.00 - 37.20	33.90 - 38.50	0.80 - 1.00
Free SiO_2	N.D.	N.D.	N.D.
Cl	N.D.	N.D.	N.D.

Raw mix: Raw mix is considered as one component, as the limestone which is feeding the plant is used as it is, without any corrections. It has the following analysis and modulus:

SiO_2	10.50 - 13.50		
Al_2O_3	3.00 - 3.70		
Fe_2O_3	1.60 - 2.10		
CaO	41.50 - 43.50	S.M.	2.10 - 2.50
MgO	2.80 - 3.00	A.M.	1.70 - 2.00
SO_3	N.D.	L.S.F.	1.00 - 1.25
K_2O	N.D.		
Na_2O	N.D.		
L.O.I.	35.50 - 37.00		
Cl	N.D.		
Free SiO_2	N.D.		
Fineness	15 - 18% on 170 mesh and 1.0 - 2.2% on 72 mesh		

$CaCO_3$	75.00 - 78.00
$MgCO_3$	4.50 - 6.00

Clinker: The produced clinker has the following range of analysis:

SiO_2	22.20 - 24.00
Al_2O_3	6.40 - 7.20
Fe_2O_3	3.20 - 4.00
CaO	60.00 - 62.50
MgO	3.90 - 4.30
SO_3	N.A.
K_2O	N.D.
Na_2O	N.D.
L.O.I.	0.40 - 1.50
S.M.	2.00 - 2.40
A.M.	1.60 - 2.00
L.S.F.	0.79 - 0.84
C_3S	10.00 - 32.00
C_2S	42.00 - 65.00
C_3A	9.50 - 12.70
C_4AF	10.00 - 12.00
C_3S/C_2S	0.24 - 0.49
L.P.	30.00 - 33.00%
F.L.	1.00 - 2.80%
C.L.W.	1,100 - 1,350

Process: Wet (2 kilns; 1 and 2) and suspension preheater (2 kilns; 3 and 4), without bypass, and with grate coolers to the four kilns.

Fuel: Coal, with 29.0 - 35.5% ash, 3.0 - 4.7% moisture and 3,900 - 4,500 kcal/kg U.H.V. Coal has residue of 14 - 18% on 170 mesh and 1.0 - 1.5% on 72 mesh.

Capacity:	1	2	3	4	
Design	600	600	1,200	1,200	mtpd
Obtained	600	600	1,140	1,140	mtpd
Utilization factor:	100	100	95%	95%	

Firing system: Indirect system

% of primary air: Not available

% ash contribution to clinker: 7 - 10%

Fuel consumption: 1,450 - 1,550 kcal/kg (wet)
950 - 1,050 kcal/kg (dry)

Ash analysis:

SiO_2	61.00 - 62.50
Al_2O_3	26.00 - 27.00
Fe_2O_3	8.50 - 10.50
SO_3	N.D.
Others	2.00 - 2.50

Lifetime of bricks: 45 - 60 days

Thickness of coating: 6 - 8"

% of dust: N.A.

Temperature, °C:

	Wet Kiln	Dry Kiln
Burning	1,400 - 1,500	1,350 - 1,450
Kiln inlet	190 - 200	820 - 840
Fan	N.A.	340 - 360

Dust collector: Dust collector is through the smoke chamber in the wet process and ESP in the dry process.

Using the dust: Using the dust in the dry process, it is mixed with ground raw meal going to the silo.

Kwh/t cement: 112 for wet kiln and
117 for dry kiln

Bottlenecks:

1 To achieve CaO in clinker 64.0%, what we should do?

2 Marble is contaminated with quartz

3 Coal flushing

4 Kiln feed and raw meal flushing from weight feeders

5 Pressurization in conditioning tower and ESP

DALLA CEMENT, UPSCC
MIRZAPUR

Names of persons who participated in discussions from Dalla Cement.

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2	Mr. K. S. Shekhawal	M. O. (QC)
3	Mr. R. K. Garg	M. D. (QC)
4	Mr. K. R. Sharma	Master Burner
5	Mr. D. D. Maheshwari	Dy Manager (P & Q)
6	Mr. Joginder Singh	Dy Manager (Inst.)
7	Mr. O. P. Jain	Sr. Chem. Eng.
8	Mr. Ravinder Singh	Chem. Eng.
9	Mr. P. H. Challary	Chemist
10	Mr. Phojdar Singh	M. S.
11	Mr. R. Kumar	Q. M.
12	Mr. M. K. Sharma	Q. M.

Name of NCB Counterpart.

1	Dr. (Miss) K. Raina	Scientist

RAJASHREE CEMENT
MALKHED, GULBURGA

Rajashree Cement started in 1984 with a single unit of 1,500 mtpd production. The kiln is a 5-stage preheater with a precalciner (Pyroclone System) supplied by KHD, West Germany. The size of kiln is 3.8 m x 50 m (inside shells) and it was expected to produce about 1,750 mtpd, which was obtained, but not frequently. The percent of kiln slope is 3.5. The clinker is cooled by a grate cooler, supplied by another supplier, with an efficiency factor of about 70%. Grinding the raw materials takes place in a ball mill supplied by a crusher ahead the mill to reduce the feed. The mill is guaranteed to produce 130 mtph, but 105 - 110 is obtained. The raw materials have free SiO_2 which is about 90% of total SiO_2 in limestone or raw mix. The information collected is attached herewith.

The plant runs smoothly although it has some constraints related to the raw mill, grate cooler, free silica in the raw material, formation of snowman, dusty clinker, occasionally jamming in cyclone II, etc. Fuel consumption ranges from 830 - 850 kcal/kg clinker (which is considered relatively high). The following are the observations and the recommendations:

1 Higher coal consumption; inconsistency of fuel consumption can be related to one or more of the following factors:

a Change in size and quantity of free SiO_2 in the raw mix, as 90% of the total SiO_2 is free SiO_2 which is considered very high percent. Accordingly the mineralogy of the kiln feed is changed. Both have a great affect on the burnability.

b Fineness of raw mill (12 - 14% on 170 mesh) is considered high for raw materials having 90% free SiO_2. Of course, there is a constraint on the raw mill production which cannot produce finer product can also produce different particle size if free SiO_2 increases in the raw materials.

c Coal is ground to 10 - 11%, which is considered fine as the ash content is high (reaches to 35%). Coal is variable as it is not homogenized and is fed to the kiln with moisture (more than 1.5%). All these factors affect the variable fuel consumption, beside some other operational factors, such as primary air, secondary and tertiary airs, degree of calcinations, etc. In this respect, it is advisable to have:

i Constant operational parameters.

ii Increase coal fineness to about 12 - 14%, and maybe to higher values. Coal to kiln should have minimum moisture and 30% ash, maximum.

iii Constant feed composition (mineralogy and particle size distribution) with less residues on 170 and 72 mesh (if possible) than the present values.

iv Adjust the feed as it is detailed later.

2 Clinker snowman is formed at the cooler entrance which can be attributed to high liquid phase and/or to less quantity of air in the cooler and/or to mechanical design. In this respect, installation of air blasters at the cooler inlet and modify the cooler entrance are recommended. Pushing the burner pipe inside the kiln can help in reducing the snowman formation.

3 Variation in coal quality and quantity, moisture content and the kiln feed (quality and quantity) can result in fluctuated CO percent at the preheater outlet. In this respect, it is recommended that 90% calcination should be obtained in the precalciner, all the time. CO content at the precalciner outlet should be monitored and be kept to the minimum (0.1%).

4 Feeding the dust direct to the kiln with the kiln feed without blending, results in fluctuated operation. It is advisable that dust handling be carefully engineered.

5 Spraying reasonable amounts of water in the cooler (fifth compartment) and as long as it does not reach the clinker bed so closely, will not affect the clinker quality, but it may affect the steel structure of the cooler. In this respect, it is advisable to ask the cooler supplier.

6 An industrial gun can be used to break heavy coatings in the kiln and snowman at cooler throat. Precautions should be taken to protect the lining.

7 To decrease the amount of the clinker dust, it is advisable to increase the amount of liquid phase by increasing F_2O_3 in the raw mix. But this, without modifying the cooler, can produce more snowman. Presence of high amounts of free silica and high ash content in the coal and high percentage of primary air, can generate more dust in the kiln. All these can be related to the kiln operation, including kiln speed. In this respect, it is recommended to fix the cooler first and then modify the mix parameter by increasing the liquid phase.

8 Raw materials with high carbon content can lead to plugging the cyclones and especially cyclone II. The limestone has about 0.92% C and intermittent jamming and build-up occurred in cyclones II, III, and IV. Presence of C in the raw materials lead to early ignition which affects the SO_3 and alkalies in the system resulting in partial melting at lower eutectic point and hence sticking to the walls. Air blasters will help in continuous cleaning the systems. It is recommended to monitor the C percent regularly and determine the limit which can be tolerated.

9 In the case of using insulation bricks underneath the fire bricks, at kiln inlet, consideration should be taken to use the right bricks and not to reduce the effective kiln diameter.

10 It is recommended to keep the following parameters for the clinker, after ash absorption:

SiO_2	:	21.4%
Al_2O_3	:	5.5 - 5.7%
CaO	:	65%
S.M.	:	2.2 - 2.3
A.M.	:	1.3
H.M.	:	2.15 ± 0.02
L.S.F.	:	94 - 95%
C_3S	:	52 - 55
C_2S	:	22 - 25
C_3S/C_2S	:	2.5
L.P.	:	28%

It is advisable to decrease the fineness of the kiln feed (although there is some limitation in the raw mill), or increase the iron content slightly and accordingly the liquid phase. The latter will produce more snowman unless the cooler is fixed. Controlling the particle size of the kiln feed and especially the quartz (quantity and particle size) are essential for smooth operation in the precalciner and kiln, and energy saving. Ninety percent calcination should be achieved and run constant in the precalciner using coal quality as mentioned earlier.

11 Dried coal with about 30% ash should be used. The flame is recommended to be sharp and intense. Avoid impingement flame. Different trials should be done to obtain the optimum particle size of coal for better flammability.

12 It is recommended to use the microscope technique for quality control of the clinker. Optimum quality with an energy saving clinker can be

obtained by microscopically examining the clinker and correlating its structure to the raw mix properties, flame shape, coal properties, retention time, kiln speed, feed and coal rate, clinker grindability, cement strength, etc. Generally, C_3S with 30 - 40 microns and C_2S about 20 microns are required.

13 It is advisable to control the CaO content of the raw mix by x-ray fluorescence. Using x-ray diffraction is of great benefit especially for the presence of high free SiO_2 in the raw materials, to determine the minerals of the raw mix and the clinker.

14 It is recommended to perform the minor constituents (Cl, Na_2O, K_2O, SO_3, C, P_2O_5) for all the raw materials, by products, final products, where it is applicable. This should not be done on a regular basis, but only for records for any sudden change occurs.

15 In order to obtain high early strength, it is recommended to modify the raw mix as it is earlier recommended and the flame should be sharp and intense. Avoid lazy and long flame. Cooler should be put in correct operation.

16 In order to reduce the setting time of the cement, it is highly recommended to use natural gypsum. By increasing the C_3S amount in the clinker, the initial setting time will be decreased. Higher C_3A reduces the setting time, but it is not advisable to increase Al_2O_3, due to the presence of high free silica in the raw materials.

17. The temperature of the cement exit and cement mill should be kept at the range of 100 - 150°C. Avoid overheating the cement and low temperature.

18 The kwh/ton of cement is 135 at 3,000 cm^2/gm for OPC, in this respect, it is recommended to have an energy audit with objective of energy reduction. The raw mill is consuming more power and producing less. Considerations should be given to overcome this problem.

<u>Other subjects discussed:</u>

1 <u>Formation of hair-cracks at spun pipe</u>: This is attributed mainly to high W/C ratio and to the fine particles of cement.

2 <u>Concrete failure</u>: Can be attributed to many factors other than the cement (as long as it is complying with the specifications). These factors are water, admixture (if it is used), aggregates, moulds, method of mixing, workmanship, etc.

<u>N. B.</u>: The information collected from Rajashree Cement shows that the clinker has 0.31% K_2O and 0.21%, which represents 0.41% total alkalies as Na_2O. In

this case, this cement can be market as "low alkali cement" which is required to avoid alkali aggregate reaction and for long durability. Alkalies should be carried daily and perhaps on each shift if the cement will be market as low alkali cement. Testing at outside organizations, to confirm the results, is of great advantage.

RAJASHREE CEMENT
MALKHED, GULBURGA

Information Collected

Raw materials: Limestone, hematite and bauxite. The limestone deposits are 2 km from the plant and have an overburden of 2 mt, followed by 2 - 2½ mt of low grade limestone (72 - 76% total carbonate), then followed by high grade limestone (82 - 86% total carbonate). Both low and high grade limestone are used and the controlling point is 82 - 83% total carbonate. Additives are added to bring down the carbonate to 80%. The limestone is hard, more or less homogeneous with Bond Work Index of 14, 1 - 2% moisture and free SiO_2 of 80 - 90% of total SiO_2. The chemical analysis of the raw materials is as follows:

	Limestone	Hematite	Bauxite
SiO_2	12.50	2.60	5.98
Al_2O_3	1.50	0.80	40.60
Fe_2O_3	0.90	94.50	28.00
CaO	46.30	0.30	-
MgO	0.50	0.04	-
SO_3	0.10	0.40	-
K_2O	0.14	0.20	-
Na_2O	0.18	0.08	-
L.O.I.	37.70	0.89	23.90
Cl	0.009	N.A.	
P_2O_5	0.15		
C	0.92		
Free SiO_2	9-11		

Raw mix composition: 95.5 : 1.7 : 2.8% limestone : Hematite : Bauxite; respectively.

SiO_2	12.04		
Al_2O_3	2.82		
Fe_2O_3	2.94		
CaO	44.60		
MgO	0.40	S.M.	2.06
SO_3	0.21	A.M.	0.95
K_2O	0.16	H.M.	2.5
Na_2O	0.14	L.S.F.	1.15
L.O.I.	36.50		
CL	0.00		
Total carbonate	80.00		

$MgCO_3$	0.80
Fineness	20% - 170 mesh
	1.6% - 72 mesh

Clinker:

SiO_2	22.12
Al_2O_3	5.70
Fe_2O_3	4.10
CaO	65.20
MgO	0.81
SO_3	0.71
K_2O	0.31
Na_2O	0.21
L.O.I.	0.34
Cl	< 0.01
S.M.	2.24
A.M.	1.40
H.M.	2.04
L.S.F.	0.91
C/S	2.95
C_3S	47.6
C_2S	27.5
C_3A	8.30
C_4AF	12.40
L.P.	27.80
F.L.	1.2 - 1.30
C.L.W.	1,100 - 1,150

Process: Five-stage preheater with a pyroclone precalciner system (KHD), without an alkali bypass.

Kiln: One rotary kiln with a capacity of 1,750 mtpd which was achieved. The utilization factor of the kiln is 100%. Grate cooler is used to cool the clinker.

Fuel: Coal with splitting of 60% in the pyroclone and 40% in the kiln.

Coal analysis:

C	45.00
H	4.50
N	1.00
O	5.00
H_2O	2.20
Ash	30 - 35

Gross H.V.	4,500 kcal/kg
Net H.V.	4,200 kcal/kg

Coal firing system: Indirect

Particle size of coal: 10% on 170 mesh
0.5% on 90 mesh

% primary air: 9%; and 11% including conveying air

% of ash contribution to clinker: 7%

Ash analysis:

SiO_2	58.38
Al_2O_3	23.92
Fe_2O_3	8.28
CaO	4.83
MgO	0.98
SO_3	1.95
K_2O	0.58
Na_2O	0.31
L.O.I.	1.04
Cl	0.013

Fuel consumption: 20.3% corresponding to 830 - 850 kcal/kg clinker

Lifetime of bricks: 150 days for burning zone

Thickness of coating: 10 - 12" - unstable

Temperature:

Burning	1,250 - 1,350°C
Kiln inlet	1,040°C
Fan inlet	290 - 310°C

% of dust collected: 5 - 7%

Type of dust collected: ESP

Some operational data:

1	% primary air	11%
2	Temperature of secondary air	900°C
3	Temperature of tertiary air	800°C

Method of using the dust: Recycling in the process

Clinker quality: 10% with size - 1 mm and 5% on + 25 mm

Kwh/t cement: 135 kwh/t for OPC ground at 3,000 cm^2/gm

Breakup of kwh/t:		
	Crusher	2.66
	Raw Mill	49.53
	Coal Mill	8.85
	Clinker	35.32
	Auxiliary	0.67
	Miscellaneous	2.42
	Cement Mill	37.45
	Packing House	1.72
	Total	133.65

Bottlenecks:

1 Snowman formation

2 Dusty clinker

3 Other problems related to light buildup on cyclone II riser duct, precalciner, low raw mill production, etc.

RAJASHREE CEMENT
MALKHED GULBURGA

Names of persons who participated in discussions from Rajashree Cement.

1	Mr. N. L. Manihar	Sr. Jt. President
2	Mr. S. S. Sharma	Jt. President
3	Mr. T. R. Venugopal Rao	G. M. (T)
4	Mr. B. L. Raina	W. M.
5	Mr. S. Ramkrishna	Master Burner
6	Mr. M. V. Kori	Asst. Prod. Mgr.
7	Mr. S. K. Gupta	Dy. Chief Engr. (Process)
8	Mr. K. V. Mudda	Dy. Engr. (Process)

Name of NCB Counterpart.

1	Dr. (Miss) K. Raina	Scientist

MADRAS CEMENTS LIMITED
RAMASWAMY, RAJANAGAR
RAMANAJAR DIVISION

This plant was visited in the first mission and the visit report is shown in Annex 9 (pp. 109 - 114), of the final report dated December 1986. The purpose of this visit to this plant was to follow-up the recommendations given during the first visit besides different points to be discussed.

This plant is doing substantially very good, although it has some limitations (no raw materials preblending, no efficient raw meal blending, no coal blending). The raw mix design has been changed according to the recommendations given during the first visit and a great improvement and achievement have been gained. This report includes two parts:

a improvements achieved in clinker quality by changing the raw mix

b recommendations for the new points discussed during the second visit.

a <u>Improvements in clinker quality</u>: Previously the clinker was characterized by:

S.M.	:	2.20 - 2.40
A.M.	:	1.80 - 2.00
L.S.F.	:	90.00 - 94.00%
C_3S	:	47
C_2S	:	26

Now, the clinker has the following parameters:

S.M.	:	2.3 - 2.4
A.M.	:	1.4 - 1.6
L.S.F.	:	0.96 - 0.97
C_3S	:	54.00 - 58.00
C_2S	:	17.00 - 20.00

Granulation of the clinker in the kiln, clinker size and grindability, coating in the kiln have been greatly improved. Dust in the kiln is minimum and the strength of the ground cement for OPC (at 2,700 cm^2/gm) has been remarkably increased. Table 1 shows the chemical analysis for both the old and new clinker, while Table 2 shows the old and new compressive strength for OPC cement, ground both at 2,700 cm^2/gm.

Table 1

Clinker chemical analysis of Madras Cement Limited before and after Nov. 1986

	Before Nov. 1986	After Nov. 1986
SiO_2	21.30 - 22.00	21.10 - 21.30
Al_2O_3	5.80 - 6.40	5.30 - 5.50
Fe_2O_3	3.00 - 3.50	3.50 - 3.90
CaO	64.80 - 65.50	65.30 - 66.30
S.M.	2.20 - 2.40	2.30 - 2.40
A.M.	1.80 - 2.00	1.4 - 1.60
L.S.F.	0.90 - 0.94	0.96 - 0.97
C_3S	47	55
C_2S	26	18
C_3A	10	8
C_4AF	9	12
L.P.	28.7	28.2
C_3S/C_2S	1.8	3.00

As it can be seen, a great improvement has been achieved in the clinker composition, based on Bogue Formula; although the S.M. is the same, but the new clinker has less SiO_2 and almost the same percent of R_2O_3. Al_2O_3 is decreased and Fe_2O_3 is increased for the new clinker, and thus A.M. is reduced in comparison to the previous clinker. L.S.F. has been increased due to high percent of CaO. As a result C_3S is increased and C_2S is decreased, C_3A is decreased and C_4AF is increased based on Bogue Formula. The liquid phase is slightly increased. C_3S/C_2S is greatly increased, and is considered now on the high side. The percent of free lime is the same as it was before (1.5 - 2.5%), but there is no expansion from both LeChatelier and/or autoclave. High free lime is preferable for producing the PPC. This result is reflected by XRD which was obtained from the plant and is shown in Figure 1 and 2 for old and new clinkers, respectively. Due to overlopping the peaks, comparison can be clearly made at 29.45 and 34.4 2°θ. In the previous clinker intensity is about 42 and 52% (Figure 1), respectively; whereas in the new clinker, it is about 70% and more than 80% (Figure 2). In the case of C_2S and comparing the peaks at 36.8 2°θ, the intensity is about 11% and 14% for previous and present clinkers; respectively. The area between 32 2°θ and 34.5 2°θ shows a remarkable change, where more intensity is shown for cement phases for the present clinker. As a result, the compressive strength has increased and better quality is obtained, as is shown in Table 2.

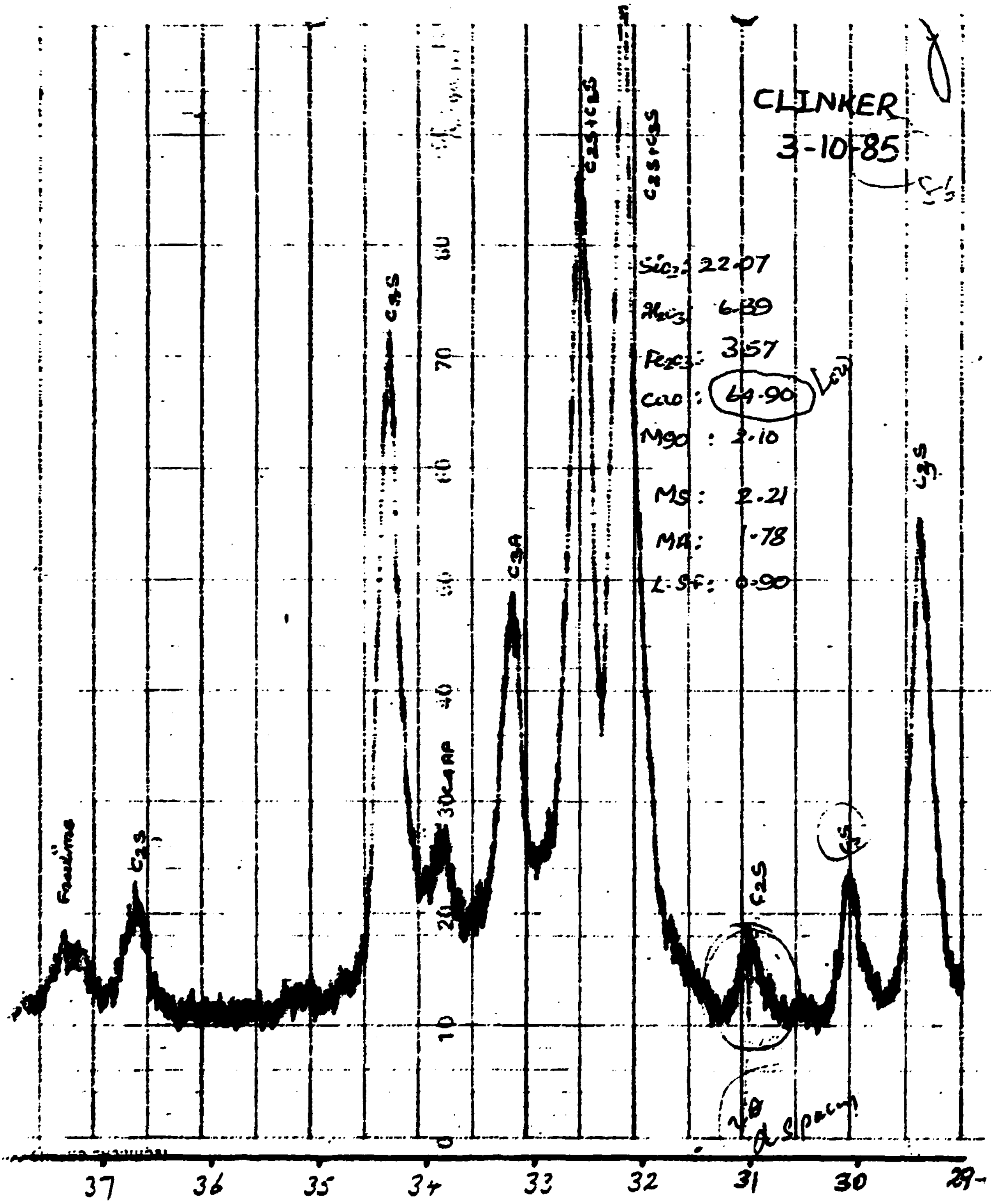

Figure 1: XRD for clinker produced before the first mission visit

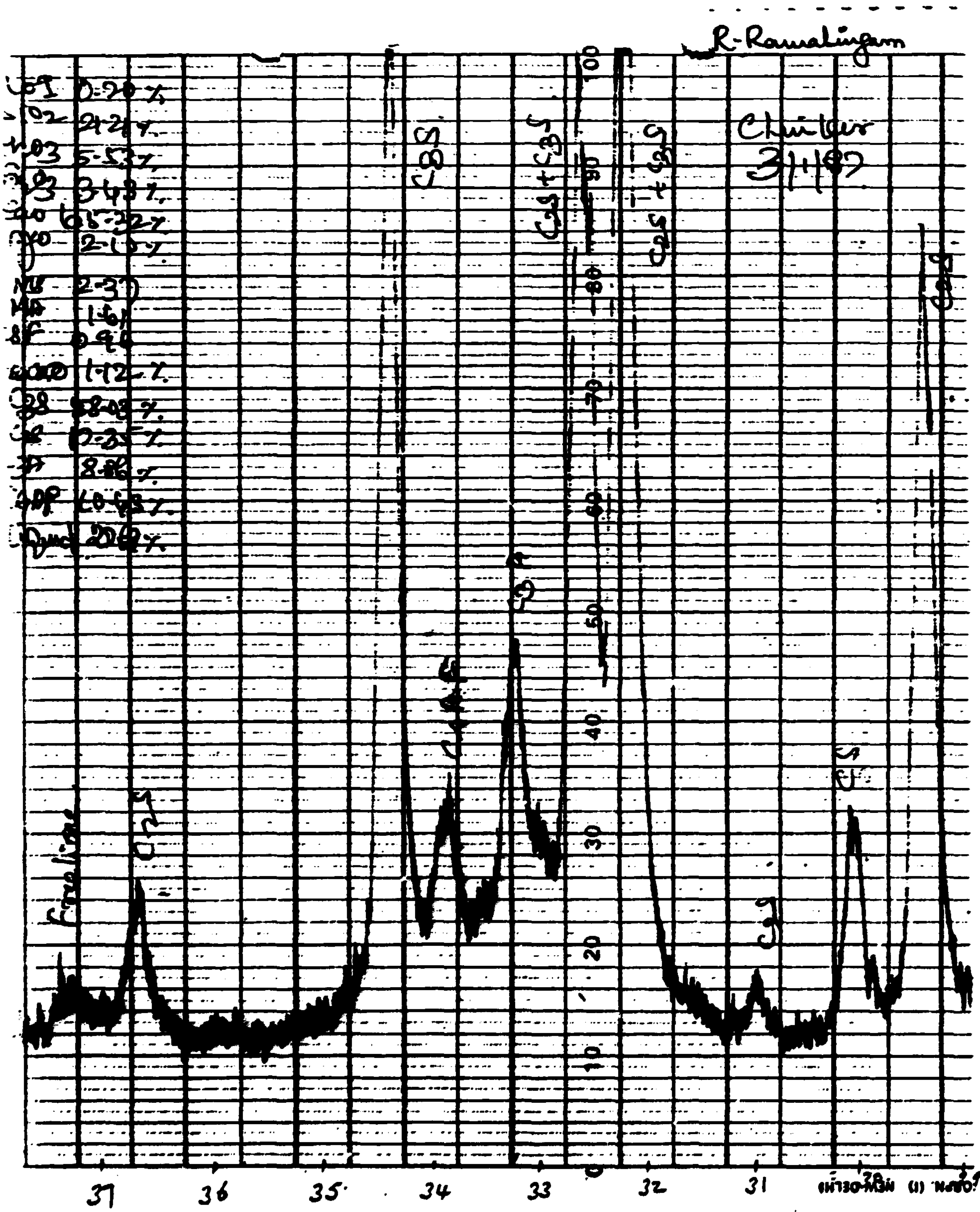

Figure 2: XRD for clinker produced after the first mission visit with the recommended mix-design.

Table 2

Compressive strength (kg/cm^2) of previous* and present cement*

Compressive Strength	Previous Cement	Present Cement
1 Day	116 - 120	200 - 220
3 Days	220 - 250	280 - 320
7 Days	300	300 - 380
28 Days	450	560

* OPC Cement with 2,700 cm^2/gm, ground in an open circuit.

With regard to the raw mix, it is recommended to keep the mix parameters as it is now without any change, except to slightly increase the iron content. Free SiO_2 in the kiln feed should be kept within the existing percent. The clinker moduli and composition should be kept as it is now. Continuous XRD of the clinker (as it is at present) is recommended to correct any abnormality.

The flame shape is long, lazy and impingement. Flame should be corrected. By obtaining a perfect flame (short, sharp and intense), more and better quality will be achieved with the new mix design.

b Recommendations for the new points discussed during the second visit:

1 Using low grade raw materials: Low grade raw materials can be used, as long as the final product will fall in the same range as the present clinker. Free SiO_2 in the raw mix should not increase than the present value and also the minor oxides (Cl, SO_3, K_2O, and Na_2O). For any new raw materials, detect the percent of P_2O_5, F and C.

2 Lignite firing in kiln: The lignite analysis has high SO_3 content, which can cause buildup. In general, lignite can be used, but it should be dry as much as possible, and a certain percentage can be used so that not much H_2O will be in the system. Using lignite, will result in changing the mix design due to the low ash content of lignite, and this should be considered, so that the produced clinker has the same specification as it does now. It is an advantage to use lignite, as it has high heating value and low ash content. Lignites contain a large amount of volatile matter, including a high percentage of noncombustible CO_2. They are characterized by their high moisture of crystallization, which on heating causes them to crumble. In the case of using lignite, the excess air is a little

bit higher than coal, but as the recommended percentage which will be used from lignite is small (about 5%), not much change can be noticed.

3 Reducing clinker temperature: The best equipment to reduce the clinker temperature exit the cooler is the grate cooler. As planatory cooler is used to cool the clinker, it is recommended to spray little water on the clinker in its way to the storage. Reducing the primary air will help in increasing the secondary air and accordingly decrease clinker temperature, relatively.

4 Using mineralizers to improve the burning process: Mineralizers have been known for a long time to reduce the burning temperature. Small amount of CaF_2 or P_2O_5 or $CaSiF_6$ or $MgSiF_6$ or boric acid can be used. Each mineralizer has its advantage and disadvantage. In this respect it is recommended to perform an experiment on the pilot plant at NCB to determine the effective material and the percentage. Complete study and evaluation of the cement for a long period of time should be performed, followed by a feasibility study. About 200°C can be saved from the suitable mineralizer, but some (if not all) has a reverse affect on the clinker and accordingly the cement quality. Sintering and cooling the produced clinker should be performed carefully.

5 Developing sulpho-aluminate phase in clinker: This clinker is produced by modifying the portland cement composition such that C_3S and C_3A are replaced by C_4A_3S and CS, and higher proportion of ferrite compound and C_2S. This clinker was produced in a research lab at about 1,200°C, but it is not considered as portland clinker. The cement produced from this modified clinker is characterized by zero C_3S and rapid hardening. It contains about 50% CaO and considerable quantities of sulphate, alumina and iron co[illegible] raw materials are required. Before producing such a cement, complete economic and feasibility studies are required, as well as how the market will respond and react to this cement and what will be the recommended applications and specifications. Long-life study of its durability is required.

6 Increase Fe_2O_3 in raw mix: As it is mentioned earl[illegible] it is recom[illegible]ed to increase Fe_2O_3 slightly. Increasing Fe_2O_3 will increase the improvement of clinker nodulization, reduce fuel consumption, increase kiln production and increase kiln coating. Fe_2O_3 should not be highly increased, as this may cause more

chocking in cooler mouth. A.M. should be kept around 1.38 in the produced clinker.

7 Use of computerized mine planning: Use of a computer in the quarry will help in better raw materials control (quality and quantity) which accordingly will result in homogeneous feed and product. In this case, all the available information (a broad raw materials investigation) should be fed to the computer with the required parameters. The program will calcuate the amount of each component required to run the plant. It is highly recommended to use computerized mine planning, and the amount of igneous rocks which will be disregarded should be indicated to the computer.

8 Use of kanker lumps in raw mix: After reviewing the available analysis and XRD, it was recommended to use those which have low free SiO_2. Those which are heavier in density and have high free SiO_2 should be disregarded. The mix design should be kept in the parameters which will produce a clinker with the same compositions as it is now. Free SiO_2 from black stone and kanker lumps should be kept as it is now. Increasing free SiO_2 will upset the kiln production, quality and quantity of clinker and clinker grindability. If the low grade limestone contains high free SiO_2, it is recommended to stop use of blackstone. Burnability test can be done in order to determine which percentage of free SiO_2 can be tolerated when using low grade limestone (kanker lumps), with and without blackstone. If the strength of the cement produced by using kanker lumps will be less, decrease its percentage to get back the strength.

9 Preblending system: Longitudinal i preblending system is recommended for its advantage in its capability of any future expansion of the plant. Blending of coal is necessary and in this case circular blending system is preferable. However, both preblending the raw materials and blending the coal are prerequisite and highly recommended. Both will ease the operation of the plant, with better quality control and improvement and stability of kiln operation and production. The clinker will be homogeneous in quality. It is also recommended, in the case of preblending the raw materials to use two beds, one is high and the other is low in Ca content. When these are mixed together (usually 1:1) in the mill, the required raw mix is obtained.

10 Chocking in the planatory cooler mouth: This can be attributed to high burning temperature and burning behind the cooler mouth, where

there is not enough time for the clinker to be cooled. High percentage of primary air will result in lower amount of secondary air, thus less amount of air will pass through the cooler mouth. In this respect, it is recommended to push the flame further inside the kiln and burn at a relatively lower temperature, and decrease the amount of the primary air. It is advisable not to alter the cooler elbow without asking the equipment supplier.

11 <u>Controlling the primary air by bypassing the air from the fan outlet</u>: It seems that the primary air is high, and controlling this amount is highly recommended as this can help in reducing fuel consumption. The percent $_2$ at kiln inlet and after I.D. fan must be carefully controlled. In this respect, it may be necessary to change the burner pipe to an efficient one, where both the air, amount of coal, flame shape can be controlled. This is the only part which is required after the raw mix has been adjusted and a high quality of clinker is obtained. By obtaining the right flame shape and burner, the maximum production and quality will be obtained.

12 <u>Reduce fuel consumption</u>: The current fuel consumption is about 950 kcal/kg clinker. It is on the highest side. As long as the leakage exists, feeding coal with moisture, primary air cannot be controlled, no weight feeder to the coal etc., therefore it is hard to reduce the fuel consumption. It is recommended to adjust all these limitations and use an efficient burner pipe with suitable coal particle size. In this case, the fuel consumption will be dropped. Cooling the clinker with planatory cooler has an affect in increasing fuel consumption, in contrast to the grate cooler.

<u>N.B.</u>: The plant is working by two fan systems (not with one fan system as mentioned earlier in the previous report). The raw mill is limited in handling the preheater gases. It is advisable to increase the mill fan to dry the mill product to about 1%.

MADRAS CEMENTS LIMITED
RAMASWAMY, RAJANAGAR

Names of persons who participated in discussions from Madras Cements.

1	Mr. P. R. Ramasubramaneya Raja	Managing Director
2	Mr. R. Natarajan	General Manager
3	Mr. S. N. Rama Raju	Administrative Manager
4	Mr. V. Jeganathan	Works Manager
5	Mr. H. V. Sethuram	Mines Superintendent
6	Mr. S. Anandan	Deputy Mines Supdt.
7	Mr. R. Murugan	Superintendent (Prodn. & Q. C.)
8	Mr. S. Natarajan	Process Control Engineer
9	Mr. S. Rajagopal	Senior Chemist
10	Mr. A. Velayutham	Works Engineer
11	Mr. R. Ramakrishnan	Development Engineer
12	Mr. R. Subramaniam	Head Burner

Name of NCB Counterpart.

1	Dr. (Miss) K. Raina	Scientist

Annex 7

EXPERT APPRAISAL

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

EXPERT : George R. Gouda
JD : Annex I
WORK PLAN : Annex II
CV : Annex III

NCB Counterparts:
(i) Dr. (Miss) K. Raina
(ii) Dr. M. M. Ali

Plant Officials Interacted:
Please refer to the main report

Location: Orissa Cement Limited, Rajgangpur (Orissa)

PRODUCTIVITY ENHANCEMENT ASPECT

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	CaF_2 as mineralizer and its effect on clinker properties	Slurry contains about 0.4% CAF_2 and small amount of phosphate		CaF_2 acts as a mineralizer and advantage of it should be taken	Recommendations were given	Lower fuel consumption
2	Raw mix design for wet process, burning process	Slurry has S.M. 2.8 - 3.0 A.M. 1.7 - 1.8. The clinker is over burned with fuel consumption: 1,500 kcal/kg		High S.M. renders the raw mix to burn and produce much dust	New parameters were given	Better clinker quality
3	Longer setting time	Initial setting time reaches to about 200 min.		XRD shows the presence of C_3A. Check the gypsum quality	Recommendations were discussed	Decrease setting time
4	Clinker phases and how the mineralizer affects them	Potential calculations does not agree with XRD analysis		This is due to the presence of mineralizer and the burning process	C_3S is increased, CaO is decreased, possibility of formation of $C_{11}A_7.CaF_2$	
5	Raw mix design	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 : Annex I
WORK PLAN : Annex II
CV : Annex III

NCB Counterparts:
(i) Mr. A. D. Agnihotri
(ii) Mr. T. N. Verma

Plant Officials Interacted:
Please refer to the main report

Location: Gujarat Ambuja Cement, Dist. Amreli (Gujarat)

PRODUCTIVITY ENHANCEMENT ASPECT

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 and mix design	An easy burning raw materials, with low alkalies (total alkalies about 0.45% as Na_2O). Clinker some time shows high expansion			New parameters were discussed and recommendations were given to achieve better quality with no expansion	
2	Compressive strength of the produced cement	Method to improve the strength			By controlling the mix as the recommendations, strength and brick lifetime will be improved. Coal is preferred to be blended for smooth operations of the kiln	
3	Preblending raw materials and its efficiency	Its efficiency is decreased by night, affecting the raw materials supply to the plant			Mechanical and electrical devices to be checked	
4	Cement mill and power consumption	Is relatively high (48 kwh/t)			Recommendations were given to convert the existing open circuit mill to closed circuit	

EXPERT APPRAISAL

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

EXPERT . George R. Gouda
JD : Annex I
WORK PLAN : Annex II
CV : Annex III

NCB Counterparts:
(i) Dr. (Miss) K. Raina

Plant Officials Interacted:

Please refer to the main report

Location: Dalla Cement, UPSCC, Dist. Mirzapur

PRODUCTIVITY ENHANCEMENT ASPECT

Sl No	Subject covered in first mission	ASPECTS COVERED: Diagnosis	Methodology	Implementation	Outcome in terms of Project Objectives: Achieved	Expected
1	2	3	4	5	6	7
1	Raw materials deposits	Shale and clay are associated with L.S. Sieving is not effective in reducing $CaCO_3$		Sieving should be more effective	L.S. with high $CaCO_3$ will be achieved	
2	Wet plant, production instability	2 slurry silos are not working. Slurry is hardened in slurry basin being only 1 mt out of 6 mt		Slurry feeding the kiln is unhomogeneous	Slurry silos and basin should be cleaned for smooth production	
3	Dry plant, controlling the pyro-processing system	T.C. & E.S.P. are working under -ve P, besides leakage from several points		Affecting the stability of the burning process	Operating T.C. & E.S.P. under the designed conditions and prevent the leakage	
4	Raw mix design, using marble is sweetener	It is expected that some difficulties will be incurred by adding the marble		Hard burning mix, affecting the clinker quality	To perform burnability test to determine the marble % and fineness of kiln feed	
5	Quality control and maintenance	Very poor for both plants, affecting clinker quality as it disintegrates by cooling. Dust through all the places		Quality control is considered not existing	Required hard work and more motivation from lab quality control and maintenance personnel	

N.B.: THIS PLANT NEEDS COMPLETE REHABILITATION AND COMPLETE SHAKE-UP, OTHERWISE IT WILL NOT SURVIVE

EXPERT APPRAISAL

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

EXPERT : George R. Gouda
JD : Annex I
WORK PLAN : Annex II
CV : Annex III

NCB Counterparts:
(i) Dr. (Miss) K. Raina

Plant Officials Interacted:
Please refer to the main report

Location: Rajashree Cement, Sadem, Malkhed, Gulburga

PRODUCTIVITY ENHANCEMENT ASPECT

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 and raw mix. Dusty clinker, intermittent of the cyclone, fuel consumption	L.S. has 90% free SiO_2, 0.15 P_2O_5 and 0.92 C. Free SiO_2 in the raw mix ranges 9 - 11%, results in hard burning mix, presence of C can be the reason for intermittent jamming of cyclone II		New parameters of raw mix design were discussed. Nothing can be done with regard to C, except continuous cleaning	To achieve better clinker quality with lower fuel consumption	
2	Flame shape, quality	Flame is bushy, ash in coal reaches 38%		This has an effect on clinker quality and unstable sintering process with more dust	Recommended flame shape was discussed. Coal with not more than 30% ash is recommended	
3	Formation of snowman	Cooling air in the grate cooler is not sufficient		Has affect on amount of vented air	To check with the cooler supplier	
4	Raw mill and fineness of the raw mix	Residues on 170 and 72 meshes are very high		Results: hard burning mix	It seems that the mill is smaller in size	

1	2	3	4	5	6	7
5	Using phosphogypsum to be ground with the clinker in the cement mill	Use of phosphogypsum will affect the setting time and the strength of cement			Recommendations were given not to use it, as long as the plant is concerned with the quality. Very small amount can be used as it has no affect on quality	
6	Reasons of hair cracks and low strength concrete	Discussions related to these subjects were held			Reasons for these two phenomena were explained. Recommendations were given	
7	Clinker microscopy		Presentation was given			

EXPERT APPRAISAL

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

EXPERT : George R. Gouda
JD : Annex I
WORK PLAN : Annex II
CV : Annex III

NCB Counterparts:
(i) Dr. (Miss) K. Raina

Plant Officials Interacted:
Please refer to the main report

Location: Madras Cement Company--Second visit to follow-up the recommendations given during the first visit

PRODUCTIVITY ENHANCEMENT ASPECT

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	Discuss the new properties of the clinker produced by the parameters given during the first visit	C_3S and strength from 1 - 28 days has been greatly increased, high clinker quality and grindability are substantially improved			Strength — Was 1 Day — 120 3 Days — 220 - 250 7 Days — 300 28 Days — 480	Now 200 - 220 280 - 320 300 - 380 560
2	Kiln operation	Smooth, less kiln dust, flame needs some adjustments			For smooth operation and more kiln production	
3	Using low quality of limestone	As long as free SiO_2 is not high and within the limit of the current mix, it can be used			Raw mix parameters, should not be changed to obtain the present quality	
4	Computerized quarry operation	Discussion was held with the concerned parties			This will help in smooth plant operation	
5	Preblending, blending and coal blending	Discussion was held and the recommendations were given			Plant requires preblending of raw materials, good blending of kiln feed and blending coal	