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16118

16 December 1986
English

# PRODUCTIVITY IMPROVEMNT THROUGH SELECTION, INSTALLATION, USE AND EVALUATION OF REFRACTORIES IN CEMENT INDUSTRY

DP/IND/84/020/11-20

I N D I A

TECHNICAL REPORT - FIRST MISSION

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

Based on the work of Miroslav Potančok,
expert for refractories

United Nations Industrial Development Organization
Vienna

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

## ABSTRACT

The Project: DP/IND/84/020/11-20

PRODUCTIVITY IMPROVEMNT THROUGH SELECTION, INSTALLATION, USE AND EVALUATION OF REFRACTORIES IN CEMENT INDUSTRY

Duration of the first mission lasted from 23 th October till 16 th December 1986. The mission was focused on the following fields of action:

- Selection of suitable refractories for various zones in rotary kilns for Indian cement plants;
- Analysing causes of refractory failure in different zones of kilns, preheaters, coolers and precalciners;
- Evaluation of high alumina, basic and insulating bricks and castables;
- The mechanisation for handling, transportation and installation of high alumina, basic and castable refractories and insulating bricks;
- Optimalization of heating up and cooling down shedules for various lining systems.

The training of refractories specialists of National Counsil for Cement and Building Materials /NCB/ by excursions to three cement plants, lectures and technical discusions was achieved.

With the help of the technical personnel from plants and through effective intemactions with NCB personnel the expert's was strengthen in the area of refractories in cement industry in the following:

- Effective diagnosis of the technical problems;
- Formulating programmes and methodologies for solving them and thus improving the productivity.

By the interaction with the plant officials their refractory problems were identified, relevant data influencing durability of lining were collected and recommendations were made. The grouped data are to be found in the National Council for Cement and Building Materials in Ballabgarh, Haryana.

The following recommendations in general were granted:

1. The content of ash in coal varies very much. To obtain better flame stability, blending of coal is inevitable.This will give more stable coating in burning zone and hence increased lining life.

2. Wedge bricks should be used instead of circular ones. These are generally accepted for cement rotary kiln as the overall stability of lining would be better. Combination of two types of wedges allows to lay the stable and flawless lining. Small type wedge /B format/ can usefully be applied for lining of deformed areas of the shell .

3. For improvement of the lining life in burning zone of the kiln especially in dry process, magnesite chrome bricks of appropriate guality /together with magnesite spinel/ should be used instead of high alumina bricks.

4. Special grades of castable refractories should be produced in India by manufacturers of refractories. These materials are low level cement content castable, steel fibre reinforced refractory castable /SFRRC/ and silicon carbide castable.

5. Measurement of shell ovality, kiln alignment, tyre clearance and shock pulse on bearings should be regularly taken with the help of NCB.

6. Content of alkalies in raw materials should be controlled for correct choice of fireclay and high alumina materials for lining kiln, preheaters and coolers.

7. Further improvement of NCB specialists for profesional determining of refractory failures by their visits of domestic cement plants and foreign institutes.

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# I. INTRODUCTION

## A. Background

Wet process practice for cement production still prevails in India /approximately 60 %/ but there is a tendency to make dry process predominant in a few years. There are more than 90 cement plant with overall yearly production of more than 40 million tons of cement per year. The new cement plants have perfect technological solutions applied by the help of well known manufacturers /a.g. FLS, Fuller and others/. The equipment of wisited cement plants proofs this affirmation.

The main role in modernisation especially of older cement plants, has National Counsil for Cement and Building Materials /NCB/ in New Delhi. With the help of specialists in all branches of cement and building materials technologies problems may be solved in the mentioned industries. NCB with his staff of specialists covers the field of investigation and research work, development of modern technologies and training of technical personnel from factories and industrial service in the cement, construction materials and partly refractory materials too.

Productivity of portland clinker is mostly dependant on the service life of refractory lining in the kiln. Almost all kiln shutdowns cause failure of refractory linings and then production of kilns falls down. Not everytime manufacturers of cement have convenient refractory materials for prolonging the lining life in rotary kilns.

Fireclay and high alumina materials with 35-70 % $Al_2O_3$ in many grades are produced and satisfy requirements of cement producers. In spite of this fact we must point out, that in many high alumina and fireclay materials high content of $Fe_2O_3$ can be observed. High content of $Fe_2O_3$ in high alumina bricks influences the quality of such materials and then the lining life in rotary kiln may be shorter.

Magnesite chrome bricks are not used in all kilns for burning zones. High prices of magnesite chrome materials may be the fact why not all kinds of such refractories are made /magnesite alumina spinel materials/.

Produced castables for certain parts of thermal equipments are convenient but some new types with special quality should be made in future. Such are low level cement content castable, steel fibre reinforced refractory castable and silicon carbide castable.

B. The purpose of the mission

Within the project STRENGTHENING NCB CAPABILITY IN PRODUCTIVITY ENHANCEMENT OF CEMENT INDUSTRY there is a sub-project "Productivity Improvement through Selection, Installation, Use and Evaluation of Refractories in Cement Industry." The aim of this first missin is to advance the refractory practice in Indian cement plants. In realization of this task separate accent has been given to the following:

- Comprehension of the present state in refractory practice;
- Analysing the causes of refractory failure in different zones and suggesting remedial measures;
- Selection of appropriate refractories for various zones in cement rotary kiln system for Indian cement plants;
- Evaluation of high alumina, basic and insulating bricks and castables;
- Strengthening the existing possibilities of the National Council for Cement and Building Materials by training refractories specialists in respect of practising methods of solving the problems.

By knowledge improvement of refractories specialists of NCB and technical personnel in cement plants more proper

selection of refractories will be achieved, such as:

- reduced energy consumption,
- better efficiency of kilns,
- reduction in kiln shutdowns.

C. Mission support

I am very grateful to the personnel of the Vienna UNIDO who thoroughly organized the whole preparation and my mission in India which proved to be very successful. My thanks belong especially to Mr.G. Hamdy, Mr.M. Ivanov, Mr.A. Makovets and others whom I had the opportunity to meet at UNIDO.

The expertise was supervised by Project Director of the National Council for Cement and Building Materials in New Delhi - Dr.M.C. Visvesvaray to whom I am highly thankful for the effective tendency of the whole project focused on the rise of the cement production in India. I also appreciate the sponsorship of the NCB director, Mr.D.B. Irani, program leader Mr.K. Kumar and organizing leader Mr.V.K. Arora who shared at the organization of my expertise in NCB Ballabgarh.

My expertise was realised in the close cooperation with Mr.S.J. Raina, Mr.S.C. Sharma, Mr.S. Agarwal, Mr.Y.P. Sethi, Mr.S. Gopal and at the workplace in Hyderabad Dr.R. Ragvendra, Mr.M. Vasudeva and Dr.V.K. Mandal to whom I am much obliged for their great part in the success which I reached during my mission at NCB as well as in cement works.

During my appointment in India I always appreciated the effort of the authorities UNDP and my special gratitude belongs mainly to Dr.M.K. Hussein, UNIDO-SIDFA and Mr. Sat Pal for the profitable and smooth development of my work.

My thanks to all other people at UNIDO in Vienna, UNDP and NCB in New Delhi who shared in my prosperous expertise durin my stay in India.

## II. SUMMARY OF FINDINGS AND RECOMMENDATIONS

### A. Findings

1. High alumina bricks are stored mainly in open while magnesite chrome bricks and castables in covered store.
2. Ash content in coal varies in the wide range.
3. Thickness of lining in the kiln is not proper.
4. Wedge bricks only in one dimension are used.
5. Alkali kontent in used raw materials is not determined.
6. Mechanical conditions of shell, tyre, bearings, kiln alignment and shock pulse measurement are not regularly performed.
7. Cality control of refractories is not a regular practice.
8. High alumina bricks of circular shape are sometimes used.
9. High alumina bricks containing 70 % $Al_2C_3$ in calcining zone are used.
10. Lining of retaining ring is not stable.
11. Composition of the raw feed allows formation of high content liquid phase in the clinker.
12. Build ups in smoke chamber and in IV. cyclone are not analysed.
13. Mineralogical composition of clinker is only calculated and not determined.
14. Castable in convenient quality is not used.
15. Special types of castables and basic bricks are not produced.

## B. Recommendations

1. All kinds of refractories should be stored in covered store. Dust and water may deteriorate their quality and reduce the durability of lining.
2. Ash content in coal varies in the range of 25-35 %. The blending of coal powder is required to get constant content of ash in fuel. This improvement alone would enable much higher stability of flame and the coating in burning zone then will be more stabilized, lining life will be longer.
3. For the rotary kiln of diameter 4,5 m, it is sufficient to use the lining of 200 mm thickness. The load on the kiln shell, tyres and rollers will then be smaller, and the total cost of lining will be reduced.
4. More stable lining can be laid be means of combining two shapes of wedge bricks for diameters about 4,5 m. Types of wedge 620 and 320 can be used.
5. Alkali content in kiln feed must be controlled as they may cause alkali bursting in discharge zone, calcining zone and smoke chamber. Build ups in smoke chamber and lower part of cyclons may be formed too. The complete chemical analysis including $SO_3$ and Cl content should be carried out, to know the reason of build up formation.
6. Kiln alignment, shock pulse on rollers, ovality of the shell and tyre clearance must be regularly taken at least after 2-3 years of the kiln operation. The job can be entrusted to NCB.
7. The following tests can be performed for quality control of new refractories in cement plant:

Chemical composition of high alumina, firecly bricks and castables - content of $Al_2O_3$, $Fe_2O_3$, in magnesite chrome bricks content of MgO, $Cr_2O_3$, $SiO_2$, CaO and $Fe_2O_3$;

Tests for bricks

- apparent porosity,
- cold crushing strength,
- shape and size tolerances,
- damage of the surface.

Tests for castable

- % water content required for vibration,
- cold crushing strength after drying at 110 °C,
- cold crushing strength after heating up to 800 °C or 1000 °C,
- total linear change after heating.

8. Wedge bricks should be used instead of circular ones. These are generally accepted for cement rotary kiln as the overall stability of lining would be higher /smaller dimensions, better adaptability and more suitable for deformed shell/.

9. High alumina bricks with lower content of $Al_2C_3$ /max. 50 %/ in the calcining zone can be used. For heat consumption economy semiinsulating bricks can be also used.

10. The monolitic lining in discharge zone should be prolonged to cover the retaining ring. Instead of castable with 90 % $Al_2O_3$ the so called LLC /low level of cement content/ castable should be used. The strength of such castable /chemical reagents as phosphates and gel $SiO_2$ are present/ increases with rise of the temperature, while in hydraulically bonded castables the strength falls down.

11. The silica content in raw feed should be increased to SM 2.2-2.4 and simultaneously $Fe_2O_3$ and $Al_2O_3$ content should be decreased to increase the viscosity of the liquid phase as well as to decrease the content of the liquid phase in

the clinker. This is to ensure stable clinker coating in burning zone.

12. As it has already been mentioned in 5. the complete analysis should be carried out to know the reason of build up formation. The chemical analysis together with the technical analysis of the reason of build up formation can be done with the help of NCB.

13. Mineralogical composition should be determined by optical microscopy measurements. The aim is to recognize the proper clinkering of raw feed.

14. Castable with higher porosity can be used for the lining in the grate cooler where the temperature changes are greater /a.i. bull nose/. In discharge zone LIC castable can be used.

15. Special grades of castables such as castable with low level cement content, steel fibre reinforced and silicon carbide should be produced by Indian refractories manufacturers. Magnesite spinel bricks should be also manufactured.

16. Further activities in realization of the project Productivity Improvement through Selection, Installation, Use and Evaluation of Refractories in Cement Industry should be done:

- closer contact between specialists from NCB in cement plants by attending and solving technical problems in cement works,
- to improve knowledge in refractory practice, advanced training of specialists of NCB in specialized institutes should be realized.

## III. THE CAUSES OF REFRACTORY FAILURE IN CEMNT ROTARY KILN SYSTEMS

### A. General

Rafractories play an important and vital role in the cement industry. Refractory lining life affects not only the production but also the economy of the plant.

Approximately during the last two decades, rotary kiln technology has changed extensively, involving mainly the suspension preheater and flash calciner techniques, where up to 60 % of the total heat energy supplied to the kiln is introduced in the kiln back end [1].

In visited cement plants, two of them are equipped with precalcining system, third plant is preparing for construct precalciner too. Therefore attention to this systems will be given.

The consequences from the mentioned changes are as follows:

- a decrease of the specific heat consumption from 1200 kcal/kg of cliker,
- a decrease in the radiation losses through the kiln shell,
- an increase in the specific production,
- a decrease in the thermal charges in the kiln crossection and volume from 5,2 Gcal/$m^2$h to 3,6 Gcal/$m^2$h,
- the averare lining performance mainly in the burning zone should be increased.

The main tasks of refractories are in the protection of metal parts of heat equipment from the direct effect of high temperature, in reducing of heat losses, participation in heat transfer while burning of raw feed and serving as working and transporting surface for the feed passing through the kiln.

Raw material components cause wear of refractories by infiltration and corrosion by melt from clinker and condensation and infiltration of alkali salts. Fuel causes chemical corrosion too, mainly in the case when the ash content is high. Thermal stresses from shell, tyres, rollers and temperature oscilations act in wear of refractories too.

B. Refractory materials used in different zones and areas of rotary kiln systems

Refractories in cement heat equipments are exposed to various temperatures, mechanical stresses and chemical attacs. From this point of view, the qualitative parameters are adequate different.

1. Refractories in suspension preheaters and precalciners. With durability of lining in this areas are not special difficulties. Lining is composed from two layers: insulatig layer is on the shell, and the second layer is of dense refractory material. For insulating layer fireclay bricks or castable is used. For working, second layer, fireclay bricks or castables are used. Fireclay bricks and castables for working layer are dense materials because of ability to withstand the abrasion.

   Some problems in lower parts of suspension preheaters are connected with build up formation. To prevent build ups, silicium-carbide materials can be used. Acid fireclay materials to prevent alkali bursting should be used.

2. Precalcining zone. The temperatures here may reach 1200 °C. Suitable refractories for this zone are fireclay bricks containing 33-37 % $Al_2O_3$, for use in the less critical parts of the zone, followed by 44 % $Al_2O_3$ fireclay brick for the higher temperature end of this section.

In precalcining zone preferable fireclay bricks with higher porosity lining can be used /for economizing heat consumption/. Cold crushing strength of such bricks must be minimally 15 MPa for ensuring convenient lining life [2]. The chemical composition of refractories depends on chemical composition of raw feed and fuel. If the content of alkalies is higher, the content of silica in fireclay materials in calcining zone used must be higher and content of alumina oxide must be lower.

The thickness of the lining is regularly the same as in other zones of the kiln. High alumina bricks for this zone are not needed.

3. Transition zone. In the transition zone of the kiln high alumina, magnesite chrome and magnesite spinel bricks are used. The choise of quality of refractory materials deepends on thermal and chemical conditions in the kiln. When the content of alkalies is higher and temperature is higher too it is better to use magnesite chrome or magnesite spinel bricks instead of highalumina bricks.

With interacting alkalies in raw materials at high temperatures alkali salts with low melting points may arise [3,4,5]:

| | | | | | |
|---|---|---|---|---|---|
| KCl | 770 °C | melting p. | NaCl | 801 °C | melting p. |
| $K_2CO_3$ | 891 °C | " | $Na_2CO_3$ | 851 °C | " |
| $K_2SO_4$ | 1069 °C | " | $Na_2SO_4$ | 884 °C | " |
| | | | $CaCO_4$ decomp. | [illegible] °C | |

Alkali salts with highalumina materials reacts to form minerals:

/3 - Korundum, $K_2O/Na_2O/.11Al_2O_3$

Kaliophilit, $K_2O.Al_2O_3.2SiO_2$

Nephelin, $Na_2O.Al_2O_3.2SiO_2$

Leucit, $K_2O.Al_2O_3.4SiO_2$

Arissing of new minerals is accompanied with changes in the volume.

At the temperature higher than 1350 °C anorthite /$CaO.Al_2O_3.2SiO_2$/ and gehlenite /$2CaO.Al_2O_3.SiO_2$/ may arise.

4. Burning /sintering/ zone. In the burning zone the burnt material reaches a temperature of 1400-1450 °C, falling at the end of the zone to about 1300 °C. As the kiln rotates its lining first receives the action of hot kiln gases at a temperature of 1600 °C, and then is coated with a layer of clinker at 1400-1450 °C [6].

Refractory materials of the burning zone must be chemically basic because of the high calcium content in the burnt raw material. In adition to the obvious properties of high fussing point and refractoriness under load and also a high flux resistance, the burning zone lining must also be volume stable, have a high thermal shock resistance, and must be able to hold of formating clinker coating to protect itself from further attack. The most satisfactory refractory materials for good coating formation and other cement kiln conditions is magnesite chrome brick bonded radially with steel sheets, which when oxidised to $FeO.Fe_2O_3$ reacts with the magnesia in the lining and yields a monolithic magnesite-ferrite bond.

Unstable coating can be obtained with high alumina refractories because of permanent reaction alkalies and lime on the contact surface between brick and feed. Therefore basic refractories are more convenient for lining the burning zone.

In basic brick even with high initial temperature relatively little liquid is formed. Selective interaction

of alkalies from clinkers with the bonding phase of refractories results in a liquid phase that promotes reaction with clinkering material as to help building up desired coating.

Condensation of salts like $CaSO_4$, $K_2Ca_2/SO_4/_3$, $K_2SO_4$, KCl and sodium salts form of deposits [7,8,9]. Salts condense from vapour phase and migrate in the liquid state within the brick until they solidifay at a temperature depending on their composition. Solidification occurs within the range of approximately 700-1000 $^{o}C$. It results in the formation of denser internal structure deep in the brick with an increased risk of cracking as a result of temperature variations.

Alkali salts can also react with $Cr_2C_3$ or chromespinel

$$MgCr_2C_4 + 2K_2O + \tfrac{3}{2}O_2 \rightarrow 2K_2CrC_4 + MgO$$

or other reactions to form hexavalent Cr ions. The presence of hexavalent chromium ions which have come from parts of the brick close to the hot face often gives these solidified internal deposits yellow colour due to the formation of $K_2CrC_4$, $K_2Cr_2O_7$ or $K_2/Cr,S/O_4$ compounds. These condensates only a little alter the structure of basic bricks because of the low ion exchange tendency between magnesium and alkali ions. Although the sulphate has almost completely filled the pores in the brick, the grain structure of the brick is still virtually intact. The filled pores are dangerous only on rapid cooling down or heating up of the kiln because of different expansion forces between layers. When shutdowns of the kiln are often and content of alkalies is high it is better to use chrome free magnesite alumina spinel bricks.

5. Cooling and discharge zone. In this zones high spalling resistance refractories are used. Lining undergoes fluctuations in temperature from the clinker at 1400-1450 °C to secondary air contact /temperature depend on type of cooler/. A dense 65-70 % high alumina brick with a very high abrasion resistance is often used in this zone.

For the nose ring /in the case of grate cooler/, or discharge end of the kiln /in the case of satelite cooler/ high alumina dense castable often are used. Alumina content in these types of castable is in the range 75-90 %.

The various lining zones overlap, and no strict division can be laid down to cover all sizes of kiln. However, as a general rule the following figures give some guidance:

| | |
|---|---|
| Calcination zone | 6 kiln diameters |
| Transition zone | 2-3 kiln diameters |
| Burning zone | 4-5 kiln diameters |
| Cooling and disch.z. | 1-1,5 kiln diameters. |

## IV. SELECTION AND EVALUATION OF REFRACTORIES

### A. The selection of refractories for rotary kiln system

The selection of refractory materials for a given zones of rotary kiln system will be determined by the conditions prevailing, e.g. highest temperature; frequency of temperature changes; chemical and mineralogical compo_sition of raw feed and fuel; mechanical stresses to which refractory materials will be exposed; the gaseous atmosphere; the presence of liquid phase with its viskosity and chemical composition; insulating capability or abrasion resistance; cost of refractories; the ability to hold coating.

It is therefore obvious, that temperature is by no means the only criterion and in fact the degree of refractoriness, or the fusing point of a material, will give only a very limited indication of how it will resist in operating conditions in cement rotary kiln system. Therefore there is a practice to characterise refractories by a combination of properties, the testing of which is the subject of continuous research and development as yet no perfect test has been devised to provide all the necessary information about the service of a refractory material in kiln system.

The main determinations for selection of refractories include:

- Apparent porosity and bulk density
- Refractoriness under load
- Permanent linear changes under high temperature
- Cold crushing strength
- Refractoriness /pyroplastic cone equivalent/
- Shape and size tolerances
- Chemical composition

- Thermal shock resistance
- Exterior damage /edges, corners, cracks and surface fusions/.

In the case of castables further determinations are important:

- Cold crushing strength after drying at 110°C
- Cold crushing strength after firing at 800°C or 1000°C
- % water needed for vibration

The above mentioned determinations are included in standards. Besides the mentioned tests further examinations of refractories can be executed:

- Determination of the creep in compression
- Determination of the modulus of elasticity in tension
- Determination of the torsion strength modulus of rigidity
- Determination of the linear expansion
- Determination of the heat conductivity
- Determination of the chemical resistence to the main charge component

The conditions for zones of rotary cement kiln system were mentioned in Chapter III.

B. The evaluation of refractories for rotary kiln system

In visited plants preferably domestic refractories are used. By manufacturer catalogues very wide grades of fireclay /FC/, high alumina /HA/, magnesit chrome /MCH/, magnesit spinel /MSP/ and light insulating bricks are produced /LWS/. Castable materials /Cast/ on hydraulic bonding are produced too.

Main characteristic of refractory materials produced in India are given in tables 1, 2, 3, 4 and 5.

Table 1

Fireclay bricks

| Characteristic | FC 25 | FC 30 | FC 35 | FC 40 | FC 45 |
|---|---|---|---|---|---|
| $Al_2O_3$, % | 25 | 30 | 35 | 40 | 45 |
| $Fe_2O_3$, % | 2-3 | | | | 2-4 |
| AP, % | 18-25 | | | | |
| BD, g/cm$^3$ | 1.9-2.1 | | 1.9-2.2 | 2.0-2.2 | 2.1-2.2 |
| CCS, MPa | 25-50 | | 25-40 | | |
| PCE-Orton Cone No | 26-28 | 28-31 | 30-32 | 31-33 | 32-34 |
| RUL, $^{o}$C | 1280-1320 | 1300-1350 | 1350-1400 | 1400-1450 | 1400-1480 |
| HC, W/K,m at 400 $^{o}$C | 0.85-1.1 | | | | |
| at 1100 $^{o}$C | 1.0-1.3 | | | | |
| PLC, % | ±0.7 | | ±1.0 | | ±1,2 |
| LE at 1400 $^{o}$C, % | 0.6-0.8 | | 0.6-0.9 | | |

Abbreviations:

AP- apparent porosity; BD- bulk density; CCS- cold crushing strength; PCE- pyroplastic cone equivalent by Orton cone No; RUL- refractoriness under load; HC- heat conductivity; PLC- permanent linear contraction; LE - linear expansion.

Table 2

High alumina bricks

| Characteristic | HA 50 | HA 60 | HA 70 | HA 75 | HA 80 |
|---|---|---|---|---|---|
| $Al_2O_3$, % | 50 | 60 | 70 | 75 | 80 |
| $Fe_2O_3$, % | 1.5-3 | | | | |
| AP,% | 16-23 | | 17-23 | 18-23 | |
| BD, $g/cm^3$ | 2.25-2.4 | 2.4-2.5 | 2.45-2.6 | 2.6-2.8 | 2.7-2.8 |
| CCS, MPa | 35-50 | 40-60 | | 40-65 | 40-80 |
| PCE-Crton | 34-35 | 35-36 | 37-38 | 38 | 38-39 |
| RUL, $^oC$ | 1400-1500 | 1450-1550 | 1450-1600 | 1450-1620 | 1450-1650 |
| HC, W/K,m at 400 $^oC$ | 1.40 | 1.45 | 1.78 | 1.80 | 1.80 |
| at 1100 $^oC$ | 1.50 | 1.57 | 1.70 | 1.80 | 1.90 |
| PLC, % /±/ at 1500 $^oC$/2 h | 0,5-1 | 0,5-1.5 | | | |
| LE at 1400 $^oC$, % | 0.7 | | 0.8 | 0.9 | 1.0 |

Note: For transition and cooling zones of the rotary cement kilns with diameter >4.0 m higher content of $Fe_2O_3$ is not convenient !

Table 4

Insulating bricks

| Characteristic | Ins60 | Ins60 | Ins63 | Ins68 | Ins70 | Ins73 |
|---|---|---|---|---|---|---|
| $Al_2O_3$, % | 35 | | | 18 | | |
| $SiO_2$ | 60 | | 63 | 68 | 70 | 73 |
| $Fe_2O_3$ | 2.5 | | | 1.8 | | |
| AP, % | 45 | | | 35 | | |
| BD, $g/cm^3$ | 1.05 | 1.25 | 1.35 | 1.60 | 1.60 | 1.60 |
| CCS, MPa | 4.7 | 7 | 11 | 20 | 15 | |
| PCE-Orton | 30 | | 20 | 18 | 26 | 26 |
| Clasification temperature, °C | 1350 | 1400 | 1250 | 1350 | 1300 | 1250 |
| PLC, % | -1.2 | +1.4 | | +1.0 | | |
| TC, W/K,m at 600 °C | 0.4 | 0.5 | | 0.6 | | |
| at 800 °C | 0.49 | 0.56 | 0.46 | 0.60 | 0.70 | 0.64 |
| at 1000 °C | 0.53 | 0.60 | 0.46 | 0.64 | 0.83 | 0.69 |
| IE at 1100 °C, % | 0.50 | | 0.60 | 0.80 | 0.75 | 0.70 |

Table 4

Insulating bricks

| Characteristic | Ins60 | Ins60 | Ins63 | Ins68 | Ins70 | Ins73 |
|---|---|---|---|---|---|---|
| $Al_2O_3$, % | 35 | | | 18 | | |
| $SiO_2$ | 60 | | 63 | 68 | 70 | 73 |
| $Fe_2O_3$ | 2.5 | | | 1.8 | | |
| AP, % | 45 | | | 35 | | |
| BD, g/cm$^3$ | 1.05 | 1.25 | 1.35 | 1.60 | 1.60 | 1.60 |
| CCS, MPa | 4.7 | 7 | 11 | 20 | 15 | |
| PCE-Orton | 30 | | 20 | 18 | 26 | 26 |
| Clasification temperature, °C | 1350 | 1400 | 1250 | 1350 | 1300 | 1250 |
| PLC, % | -1.2 | +1.4 | | +1.6 | | |
| TC, W/K,m at 600 °C | 0.4 | 0.5 | | 0.6 | | |
| at 800 °C | 0.49 | 0.56 | 0.46 | 0.60 | 0.70 | 0.64 |
| at 1000 °C | 0.53 | 0.60 | 0.46 | 0.64 | 0.83 | 0.69 |
| LE at 1100 °C, % | 0.50 | | 0.60 | 0.80 | 0.75 | 0.70 |

Table 5

Castables

| Characteristic | Cast 40 | Cast 50 | Cast 60 | Cast 70 | Cast 80 | Cast 90 |
|---|---|---|---|---|---|---|
| $Al_2O_3$ | 40 | 50 | 60 | 70 | 80 | 90 |
| BD, $g/cm^3$ | 1.8-2.1 | 2.0-2.3 | 2.2-2.4 | 2.2-2.5 | 2.3-2.7 | 2.6-2.8 |
| CCS, MPa | | | | | | |
| after drying at 110 °C | 30 | 40 | 40 | 45 | 50 | 50 |
| after firing at 1000 °C | 25 | 30 | 30 | 35 | 35 | 40 |
| PCE-Orton | 26-28 | 28-32 | 31-33 | 32-35 | 34-36 | 36-38 |
| Classification temperature, °C | 1300 | 1300-1450 | 1450-1500 | 1450-1550 | 1550-1650 | 1650-1700 |
| HC, W/K,m | | | | | | |
| at 700 °C | 0.96 | | | 1.24 | | 2.32 |
| at 1000 °C | 1.12 | | 1.27 | | | 2.15 |
| LR, % | 0.40 | 0.45 | 0.55 | | 0.60 | |
| Type of bonding | hydraulic | | | | | |

## V. A REPORT ON REFRACTORY PRACTICES, PROBLEMS AND POSSIBLE REMEDIAL MEASURES FOR THE CEMENT PLANTS VISITED

During the course of stay in India, the undersigned along with NCB-PEP team visited 3 cement plants with the programme given below:

- discussion with technical staff responsible for refractories and their applications in cement plant;
- observing the relevant areas in plant;
- based on the observations and discussion with technical personnel, recommendation for solving problems were given;
- getting technical plant data in the form of a questionnaire
- lecture on the topic "Refractory practices in cement rotary kiln systems".

Major suppliers of refractories to Indian cement plants are as follows:

1 Orissa Cement Ltd
2 Shri Nataraj Ceramic Chemical Industries Ltd
3 Orissa Industries Ltd
4 Kumardhubi Fireclay Silica Works Ltd
5 ACC Ltd
6 Carborundum Universal Ltd
7 V R W Refractories

Types of refractories used in the plants visited and their properties are given in Table 6,7,8 and 9.

TABLE - 6

## HIGH ALUMINA BRICKS

| Specification | Type of Bricks | | |
|---|---|---|---|
| | HA 70 | HA 70 | HA 70 |
| $Al_2O_3$, % | 70 | 70 | 70 |
| $Fe_2O_3$, % | 1,5 | 3,0 | 2,5 |
| AP, % | 25 | 23 | 18-23 |
| B D , $g/cm^3$ | 2,55 | 2,60 | 2,50 |
| C C S , MPa | 50 | 50 | 50 |
| PCE-Orton Cone No | 37-38 | 37 | 37 |
| RUL, °C | 1500 | 1450 | 1450 |
| PLC at 1500°C 2h, % | ± 0,5 | 1,5 | 1,5 |

TABLE - 7

## FIRE CLAY AND INSULATING BRICKS

| Specification | TYPE OF BRICKS | | | | | | |
|---|---|---|---|---|---|---|---|
| | FC 25-35 | FC 25-35 | FC 32 | FC 32-35 | FC 40 | FC 45 | Insu-lating |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Al_2O_3$, % | 25-35 | 25-35 | 32 | 32-35 | 40 | 45 | 70 ($SiO_2$) |
| $Fe_2O_3$, % | 4 | 4 | 2,5 | 3 | 3 | 20 | - |
| A P , % | 25 | 30 | 23 | 23 | 23 | 23 | 65 |
| B D , $g/cm^3$ | 2,10 | 1,80 | 2,1 | 2,0 | 2,15 | 2,2 | 0,75 |
| CCS, MPa | 20 | 15 | 27,5 | 25 | 40 | 30 | 1,22 |
| PCE-Orton | 28 | 28 | 30 | 30 | 32 | 33 | 16 |
| RUL, °C | 1350 | 1350 | 1350 | 1380 | 1450 | 1450 | 1100 |
| PLC at 1400°C/ 2 h % | ±1,2 | ± 1,2 | ± 1 | ± 1 | ± 1 | - | - |

## TABLE - 8

## MAGNESITE CHROME BRICK

| Specification | Values |
|---|---|
| MgO, % | 75,0 |
| $Cr_2O_3$, % | 12,0 |
| $Al_2O_3$, % | 3,3 |
| CaO, % | 1,9 |
| $SiO_2$, % | 1,0 |
| $Fe_2O_3$, % | 3,0 |
| A P , % | 16 - 20 |
| B D, $gm/cm^3$ | 2,9 - 3,05 |
| CCS, MPa | min 40 |
| PCE - Orton | 40 |
| RUL, °C | 1 720 |
| PLC at 1500°C 2h, % | ± 0,3 |

## TABLE - 9

## CASTABLES - HYDRAULIC

| Type of Castable/ Specification | Cast. 45 | Cast. 55 | Cast. 65 | Cast. 80 | Cast. 88 | Cast. 90 |
|---|---|---|---|---|---|---|
| $Al_2O_3$, % | 40-45 | 50-55 | 60-65 | 75-80 | 88 | 89-91 |
| $Fe_2O_3$, % | 3,0-4,0 | 1,0 | 1,0-1,5 | 3,0-4,0 | 0,5 | 0,4 |
| B D, $g/cm^3$ | 2,1 | 2,1-2,2 | 2,4 | 2,6 | 2,8-2,9 | 2,8 |
| CCS/110°C, MPa | 30 | 50 | 30 | 30 | - | 35 |
| CCS/Temp.°C, MPa | 25/1300 | 60 | 25/1500 | 45/1450 | 80 | 40/1550 |
| PCE - Orton | 23 | 28 | 33 | 32 | 33-34 | 36-38 |
| Max. grain, mm Size | 3,0 | - | 3,0 | 3,0 | - | 4,0 |
| % Water/Vibr. | 12,0 | - | 10,0 | 12,0 | - | 10,0 |

NARMADA Cement CO LTD
Post Box No. 10
Jafrabad 364 540
Amreli (District)
Gujarat

Relevant Technical Plant details are given in Annex 2

OBSERVATIONS

1. High alumina bricks are stored in open while magnesite chrome bricks and castables in covered store.
2. Ash content in coal varies in the range 25 - 35 %
3. Thickness of lining in the kiln is 229 mm
4. Wedge, bricks, only in one dimensions are used
5. Content of alkalies is not determined in raw materials used (coal, raw feed)
6. Kiln alignment and shock pulse measurement on rollers are not done
7. Measurement of shell ovality was done by NCB.
8. Quality control of refractories is not a regular practice
9. High alumina bricks of circular shape are used in transition zone
10. In calcining zone, high alumina bricks containing 70 % $Al_2O_3$ are used
11. Narrow part of precalciner inlet pipe is worn out by abrasion easily
12. Bull nose part of lining inside the grate cooler often cracks
13. Nose ring in discharge zone has short lining life (dense castable containing 90 % $Al_2O_3$ is used)

RECOMMENDATIONS

1. All kinds of refractories must be stored in covered store. Dust and water can deteriorate their quality.

2. The blending of coal powder is required to get constant content of ash in fuel. The coating in burning zone then will be more stable.

3. For the rotary kiln, used, it is sufficient to use 200 mm thickness of the lining. The load on the kiln shell tyres and rollers will then be smaller, and total cost of lining will be reduced.

4. More stable lining can be laid by means of combining two shapes of wedge bricks for diameter 4,57 and thickness of the lining 200 mm.

5. Content of alkalies in kiln feed must be controlled as they may cause alkali bursting in discharge zone and smoke chamber.

6. Kiln alignment and shock pulse measurements on rollers must be measured after 2 - 3 years of operation of the kiln. The job can be entrusted to NCB.

7. The gap between shell and tyre was measured by NCB but this requires to be supplemented by measurements of shell ovality, alignment of the kiln and shock pulse on bearings /transition zone/ as is recommended in 6 above.

8. For quality control of new refractories in cement plant, the following tests can be performed:

   a/ Chemical composition

   High alumina and fireclay bricks - content of $Al_2O_3$ and $Fe_2O_3$, magnesite chrome bricks - content of MgO, $Cr_2O_3$, $SiO_2$, CaO, and $Fe_2O_3$ ; insulating materials - content of $SiO_2$, $Al_2O_3$, $Fe_2O_3$.

   Castables - content of $Al_2O_3$, $Fe_2O_3$.

b/ Apparent porosity
c/ Cold crushing strength
d/ Shape and size tolerances
e/ Damage of the surface.

For castable:

- % water content required for vibration
- CCS after drying at 110°C
- CCS after heating up to 800°C or 1000°C
- total linear change after heating.

9. The wedges instead of circular bricks are more convenient for all zones of the kiln (smaller dimensions, better adaptability and more suitable for deformed shell)

10. High alumina bricks with lower content of $Al_2O_3$ /max 50 %/ can be used in the calcining zone

11. SiC castable lining of thickness 15-20 mm can be used for the narrow part of precalciner inlet pipe. Such material can prevent abrasion. Content of SiC in castable should be 60 % (min).

12. Castable with higher porosity can be used for the lining of bull nose in the grate cooler.

13. The lining life of the discharge end can be improved by:

a/ Prolonging the length of castable lining from 0,5 m to 1,0 m.

b/ Instead of castable with 90 % $Al_2O_3$, use the so called LLC (low level of cement content) castable. The strength of such castable (chemical reagents as phosphates and gel $SiO_2$ are present) increases with rise of the temp., while in hydraulically bonded castables the strength is falling down.

In both cases free anchoring system may be used. The metallic plates with openings are welded to the shell, pulling the normal anchors through the openings.

TEXMACO LIMITED
Yerraguntla 516 309
Cuddapah (Dist)
Andhra Pradesh

Relevant technical data are given in Annex 3

OBSERVATIONS

1. In the pipe from smoke chamber to IV Cyclone build ups are formed which caused frequent kiln stoppages.
2. Very heavy coating loss can be observed in the burning zone, where high alumina bricks are used for lining. High alumina bricks contain 1, 5 % of $Fe_2O_3$.
3. In the middle part of burning zone, shell of the kiln is visibly deformed.
4. For brick lining, two types of wedges 420 and 620 are used. The same wedges are also used for lining the zone where shell is deformed.
5. Lining on retaining ring is not stable and it was observed that the retaining ring became exposed during the operation of the kiln.
6. Bull nose in cooler is worn out easily in spite of use of high alumina castables.
7. Hugh alumina bricks are stored in open, lying on the ground. Castable is stored in covered storage yard.
8. The composition of the raw feed allows formation of high content of liguid phase in the clinker.

The viscosity of liquid phase must be very low because of low content of $SiO_2$ (SM in feed = 1,44) and high content of $Al_2O_3$ and $Fe_2O_3$. Liquid phase can easily penetrate into pores of high alumina bricks and react with refractory components.

9. Mechanical condition of shell, tyre and bearings is not measured.

10. Mineralogical composition of clinker is calculated.

RECOMMENDATIONS

1. The complete chemical analysis including alkalies, $SO_3$ and Cl content should be carried out, to know the reason of build up formation. The following recommendation can be given to prevent the build ups in IV cyclone:

   a/ to lower the smoke chamber temperature (below 960°C) by using lifter plates (refractory steel) in calcining zone to ensure the better heat changing effect;

   b/ to provide the refractory steel lifters into the inlet zone of the kiln.

2. The silica content in raw feed should be increased to SM-2,2-2,4 and simultaneously $Fe_2O_3$ and $Al_2O_3$ content should be decreased to increase the viscosity of the liquid phase as well as to decrease the content of the liquid phase in the clinker to ensure stable clinker coating in burning zone.

3. For deformed area of the shell, small type of bricks so called B-format can be used.

4. In the burning zone, especially where coating is formed magnesite chrome bricks should be used instead of high alumina bricks.

Same wedges 420 and 620 type or 320 and 620 type can be used with metallic joints sheetsin the ring (thickness 1 mm).

5. The monolithic lining, in discharge zone should be prolonged to cover the retaining ring. If the problem continues, the retaining ring may be removed because of conical ending of the shell which can withstand the pressure caused by lining (slope of the kiln).

6. It is recommended to use castable with higher porosity instead of dense one. Such castable enables easy evaporation of the water and will be able to withstand the thermal shocks.

7. High alumina bricks should be stored in covered storage to protect them, against water soaking and dust.

8. The recommandation is same as given in point 2 above.

9. Measurement of shell ovality, kiln alignment, tyre clearance and shock pulse on bearings must be regularly taken.

10. Mineralogical composition can be calculated by optical microscopy measurements. The aim is to know the proper clinkerization of raw feed.

RAYMOND CEMENT WORKS
Gopalnagar 495 663
Bilaspur (Dist)
MADHYA PRADESH

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Technical data are given in Annex 4

OBSERVATIONS

1. In the smoke chamber, build ups are formed, lining in this area is castable with 55 % $Al_2O_3$ content.

Fusing of the surface is observed.

2. High alumina bricks in transition zone are worn out early (bursting of the surface).

3. The end edge of nose ring is cracking. Materials used for lining is castable, sometimes plibrico strong mix" with 45 % $Al_2O_3$ content castable is also used.

4. The separating beam in grate cooler has short life. Beam is made of 55 % $Al_2O_3$ castable with anchors welded to the arch of the cooler.

5. Two types of wedges /620 and 320/ are used for lining.

6. Facilities for measurement of ovality of the kiln, kiln alignment and shock pulse on bearings are not available.

7. The brick lining is mechanised.

RECOMMENDATIONS

1. Build ups in the smoke chamber can be caused by alkalies or by formation of spurrite type minerals. In both cases refractory lining is not responsible for this phenomenon. Build-ups only partially can be reduced by using SiC type of castable in a layer of approximately 20 mm thick. Smelting of the surface of lining can be caused by alkalies, in such a case it is better to use acid kind of castable for lining.

2. It is recommended to use direct bonded magnesite chrome bricks in the transition zone instead of high alumina brick ti improve the lining life in this zone. As in this zone, no stable coating is formed over the surface of the bricks, these are directly exposed to the processing material and gases present in kiln.

So surface of bricks get reacted with alkalies and partially with CaO to form feldspar. Reaction of CaO and alkalies with MCH brick is not so vigorous.

3. The cracking of the edge of nose ring can be caused by large ash coating falling. LLC castable (instead of castable 90) with mullite type of grains should be used. If content of alkalies are high, the castable with lower content of $Al_2O_3$ can be used.

4. The separating beam hanging from the ceiling of grate cooler into it can be made from steel fibre reinforced refractory castable (SFRRC).

5. The lining of deformed area of shell, smaller type of wedges (B 620 and B 320) can be used.

6. To prevent deformation of the shell, regular measurement of ovality, gap, kiln alignment and shock pulse must be taken. NCB can provide this facility to the plant.

7. Periodic quality control checking of bricks and castables is necessary.

## VI. STRENGTHENING OF NCB IN THE FIELD OF REFRACTORIES FOR CEMENT INDUSTRY

At present the activity of a group of specialists in NCB for refractories is directed to the following areas:

- the research of properties of newly developed materials in NCB conditions,
- the evaluation of manufactured materials qualitative parameters according to Indian Standards,
- special high - melting, microscopic, X-ray investigations and termal tests,
- training of employees in the cement industry.

For the more efficient operation of NCB in the aim of the cement production enhancement in India it is advisory:

1. Creation of a staff of specialists.
   There is a need of training more specialists for the research, realisation and consulting activities in the sphere of refractories to ensure the more intensive contact between cement works and NCB specialists.
   At least fifteen experts are needed in a group focused on refractories with their orientation on:

- Testing and evaluation of qualitative parameters of the used and new kinds of shaped refractories and refractory concrete.
- Control, measurement, evaluation and preparation of a precaution plan in the mechanical condition especially of cement rotary kilns.
- Expertise in solving actual problems in cement works; analysis and proporsals to eliminate difficulties.
- Training of employees in cement industry by means of lectures and seminars where they are informed

about checking tests and laboratory equipment for refractories.

2. Instrument equipment

At present NCB instrument equipment enables to perform tests by Indian Standards for Refractories.

To strengthen the effective aid in cement industry it is important to:

- Equip a laboratory for refractory testing of castables and processing, including the machinery convenient to use these materials in cement works (vibratories, gunite and ramming machines)
- Equip a research workplace with electronic microprobe to study reactions refractories matrix
- Equip highthermal laboratory with instruments for measurement of nonstandard properties of refractories (creep in compression, modulus of elasticity in tension, torsion strength modulus of rigidity).

3. NCB experts training

For the closer contact among specialists it is advisory to ensure:

- Permanent personal attendance of experts in cement works to solve arising problems in refractories.
- Attendence of experts at temporary employment in research institutes applying refractories in cement works and in institutes of refractory manufactures.

The temporary employment is proposed in the following institutes:

Research Institute for Cement, Moscow, U.S.S.R.
Didier Werke, Wiesbaden, West Germany
Höganäs AB, Höganäs, Sweden

Refratechnik GmbH, Göttingen, W. Germany
Veitscher Magnesitwerke AG, Vienna, Austria
Plibrico MBH, Vienna, Austria

## LIST OF TABLES



## LIST OF ANNEXES

UNITED NATIONS

April 1985

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

UNIDO

PROJECT IN THE REPUBLIC OF INDIA

## JOB DESCRIPTION

DP/IND/84/020/11-20

**Post title** Expert in Productivity Improvement through Selection, Installation, Use and Evaluation of Refractories in Cement Industry

**Duration** Two months in the first mission with the possibilities of further Four months in subsequent missions.

**Date required** 1 May 1985

**Duty station** New Delhi, with extensive visits to cement plants and with the possibility of travel to other CRI-Units within the country, as may be required.

**Purpose of project** To improve the total productivity factor in the industry and the technological levels of the various units of the cement industry in India through strengthening of the national centre - the Cement Research Institute of India (CRI).

**Duties** The expert will be attached to CRI as a part of the international team lead by the Project Director, and will work under the supervision of the Institute's Chairman and Director General..

Whilst the field of work of the expert will cover the entire spectrum of activities relating to modernisation of refractory practices in Indian cement plants, the special thrust will be in the following areas:

First Mission:
- Analysing causes of refractory failure in different zones and suggesting remedial measures;
- Selection of appropriate refractories for various zones in a cement rotary kiln system for Indian cement plants;
- Evaluation of high alumina, basic and castable refractories and insulating bricks.

Subsequent Missions:
- The mechanization for delining, transportation and installation of these bricks;
- Optimization of heating up and cooling down schedules for various lining systems;
- Development of simulative testing method for evaluating burning zone refractories.

..../..

Applications and communications regarding this Job Description should be sent to:

Project Personnel Recruitment Section, Industrial Operations Division
UNIDO, VIENNA INTERNATIONAL CENTRE, P.O. Box 300, Vienna, Austria

V.81-33106

In the above areas the expert will specifically be expected to assist CRI in strengthening the existing capabilities of CRI in:

a. Effectively diagnosing technological problems and productivity constraints in cement industry;

b. Formulating programmes and methodologies for solving technological problems and improving productivity;

c. Implementing solutions as arrived at in (b) above

the enable it, in co-operation with the industry, to achieve increase in capacity utilization, decrease in kiln downtime and reduction in heat consumption, and establish a central data base at CRI for monitoring the various productivity indicators.

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

Qualifications: Ceramic/Refractory/Chemical Technologist with 20 years of extensive experience including adequate experience at responsible and senior levels in Refractory Industry with specialization in cement plant refractory lining. The expert should have an intimate background of productivity management in relation to the above and be familiar with methodologies of studies for Productivity Enhancement.

Langunge: English

Background Information: Today the cement industry in India comprises 94 cement plants - having a total annual installed capacity of 36.5 million tonnes. Refractories used in Indian cement plants are mostly alumina bricks (of 35, 50 and 70 percent Aluminum Oxide content only) for various zones in the kiln. Some of the new plants of higher capacities are using basic bricks as well. Castables are used in several plants but monstly in burner pipes, hoods, cyclone preheaters etc.

Cement Research Institute of India (attached to the Ministry of Industry, Government of India) 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 on productivity enhancement and modernization, and a number of cement plants have already derived benefits from this programme.

**ANNEX 2**

1 **Name of the Plant & Address**

NARMADA CEMENT CO LTD
POST BOX No.10
DIST AMRELI JAFARABAD 364 540
GUJARAT

2 **Name and the designation of the technical staff**

Mr H S PATEL, DY WORKS MANAGER
Mr V M NENE, PRODUCTION MANAGER
Mr P S MAZUMDAR , ASSTT PRODUCTION MANAGER

3 Incharge refractory section

Mr V M NENE, PRODUCTION MANAGER

4 Capacity of the plant per year

One Million Tonne

5 Process

Dry Process with four stage preheaterand flash calciner

## 6 TECHNICAL DATA OF THE KILN

| Process | Capacity | Year of installation | Supplied by | Kiln dim (Lxd) | Shell thickness mm | RPM | Type of preheater/ precal/ cooler |
|---|---|---|---|---|---|---|---|
| Dry | 1 M Tonne | 1982 | Fuller's U S A | 67.5x 4.57 | 25 mm/ 38mm | 0.3 to 3.3 | Suspension Flash calciner Four stage susp. preheater Two stage grate cooler |

7 Chemical composition kiln feed (%)

| LOI | $SiO_2$ | $Al_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | $SO_3$ | Cl |
|---|---|---|---|---|---|---|---|---|
| 35.50 | 12.50 | 4.20 | 45.0 | 0.5 | - | - | - | - |

| AM | SM | LSF |
|---|---|---|
| 2.4 | 2.10 | 1.09 |

size distribution of the kiln feed 170 mesh 20.0% 72 mesh 6.5%

8 Composition of clinker (%)

| $SiO_2$ | $Al_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | $SO_3$ | Cl |
|---|---|---|---|---|---|---|---|
| 22.5 | 6.5 | 65.6 | 1.0 | 8-10 | - | - | - |

| FREE CaO | $C_3S$ | $C_2S$ | $C_3A$ | $C_4AF$ |
|---|---|---|---|---|
| 1.5-2.5 | 40-45 | 28-33 | 8-10 | 10-12 |

9 Fuel:

Ash content, % Max 35 Min 25 Average 30

Chemical composition of ash, %

| $SiO_2$ | $Al_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | $SO_3$ | Cl | $Fe_2O_3$ |
|---|---|---|---|---|---|---|---|---|
| 58.5 | 18.5 | 12.5 | 0.60 | - | - | 1.8 | - | 8.0 |

Calorific value, kcal/kg 4600

Consumption of fuel/tonne of clinker 13%

Average heat consumption : Kcal/kg clinker 840

Size distribution of fuel 170 mesh (40%) 100 mesh (25%)

Whether coal feed rate is controlled Yes

10 Kiln Operation details

| | |
|---|---|
| Temperature of the shell in burning zone | 310/320°C (Max) |
| Measurement of the shell temperature | Radiation Pyrometer and Shell Scanner |
| Temperature of the flue gases | 340°C (Same gas is diverted to Raw mill for limestone drying) |
| Secondary air temperature | 700°C |
| Frequency of Kiln stoppage (a) Without fuel | Once a month |
| (b) Lower feed with fuel | 7 to 8 times |

Shell ovality — Measurement carried out only once

Frequency of measuring of ovality

Measuring the gap between tyre and kiln shell — Three Nos. At successive distance of 20 m from discharge end of kiln

Metallic retaining rings and their position in the kiln. The length the flame and its position in the kiln whether auxiliary drive is available — Yes

11 Refractory lining practice

11.1 Zoning of the rotary cement kiln

| Zone: | Drying | Calc. | Transition | Burning | Cooling | Discharge |
|---|---|---|---|---|---|---|
| Length, m | 27 | | 15 | 20 | 5 | 0.5 |
| grade of refractories | HA 70 | Lofal 70 ($2-2.5\%Fe_2O_3$) | | Mag chrome (7% MgO) | HA 70 | HA Castable(90% $Al_2O_3$) |
| Shape of bricks | | | | | | |
| Lining thickness | 229 mm | | | | | |
| Lining life | >4 years | 6 months | | 8 months | 12 months | 6 months |

Mg Chrome bricks are wedge type
HA 70 & Lofal - 70 are Arch type

| | | |
|---|---|---|
| Supplier of refractories | Silica-alumina | Dalmia Refractories (Nataraj Ceramics) |
| | Magnesitchrome | Orissa cement Ltd |
| | Insulating | Dalmia Refractories |
| | Castable | Acc / Carborundum Universal |
| | Others | |

| | | | | |
|---|---|---|---|---|
| Lining Construction | Ring | binding | Castable | Others |

Combination of brick shape — Same size and shape with key bricks

Kind of expansion joints — Axial radial — Cardboard fitted with every brick Metal shim

Lining with mortor -

Admixtures to mortar used (water, chemicals)

Lining in dry way

Installation techniques used — Using Mechanical jacks

Heating/cooling schedules — 36 hrs heating/24 hrs cooling

Coating details : Length of coating, m 20.
thickness 150-200 mm
Uniformity -
stability -
nature (porosity / hardness/ glass) hard mass

Remark about type of wear/reasons -

How do you analyse the performance of refractories in different zones -

Areas of frequent problems -transition zone/hot-spring

Please give refractory lining charts

11.2 Preheaters, coolers, firing hood, burners Refractories used in
Preheater ducts - castable
Cyclone - castable in cone position
Bricks for cylindrical portion and roof
Cooler-sidewall lined with castable and roof with bricks
Firing hood lined with castable
Burner pipe lined with castable

average refractory consumption per tonne clinker produced 0.75 kg for kiln (1985)

11.3 Storage of refractories: Silica-alumina bricks In covered room/In open yard with concrete floor and Tarpaulin cover
magnesitechrome bricks Inside covered room
castables, mortars " " "

11.4 Quality control measures adopted for selection of refractories. (1) Dimension (2) CCS (3) Chemical analysis (4) AP & BD (5) PCE (6) RUL (8) PLC (9) HMOR

12.0 Mechanical Maintenance of Kiln -

12.1 Kiln alignment

12.2 Shock pulse measurement of the bearings

ANNEX 3

1 Name of the Plant & Address

TEXMACO LTD., YERRAGUNTLA 516 309
CUDDAPAH (DIST); ANDHRA PRADESH

2 Name and the designation of the technical staff

i) Sri S.N. Kanchal - Chief Executive
ii) Sri B.M. Sivasankar - General Manager (Works)
iii) Sri P.G. Kutty - Chief Electrical Engineer/commission Incharge
iv) Sri U.K. Dubey - Production Manager
v) Sri C.S. Reddy - Chief Mechanical Engineer
vi) Sri M.G. Naushad - Deputy Chief Burner
vii) Sri M.R. Rajan - Production Engineer

3 Incharge refractory section

Production Manager
Deputy Chief Burner

4 Capacity of the plant per year

0.5 Million Tonnes

5 Process

4 SP Dry Process

6 TECHNICAL DATA OF THE KILN

| Process | Capacity | Year of installation | Supplied by | Kiln dim (Lxd) | Shell thickness mm | RPM | Type of preheater/ precal/ cooler |
|---|---|---|---|---|---|---|---|
| Dry | 1500 TPD | 1985 | L&T FLS design | 4.55 m x 68 m | 28 | 1.5 | FLS 4 stage preheater |

7 Chemical composition kiln feed (%)

| LOI | $SiO_2$ | $Al_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | $SO_3$ | Cl | $Fe_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|
| 35.0 | 12.04 | 4.96 | 43.62 | 1.15 | - | - | - | - | 3.48 |

| AM | SM | LSF |
|---|---|---|
| 1.04 | 1.44 | 1.46 |

size distribution of the kiln feed

8 Composition of clinker (%)

| $SiO_2$ | $Al_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | $SO_3$ | Cl | $Fe_2O_3$ |
|---|---|---|---|---|---|---|---|---|
| 22.24 | 8.14 | 62.11 | 1.30 | - | - | - | - | 4.9 |

| FREE CaO | $C_3S$ | $C_2S$ | $C_3A$ | $C_4AF$ |
|---|---|---|---|---|
| 1.54 | 22.41 | 42.84 | 11.71 | 17.34 |

9 Fuel:

Ash content, % 40.2 Max 33.4 Min 36.3 Average

Chemical composition of ash, %

| $SiO_2$ | $Al_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | $SO_3$ | Cl |
|---|---|---|---|---|---|---|---|
| 62.0 | 22.8 | 72 | 1.0 | 7.0 | | | |

Clarific value, kcal/kg 2000 Kgs -
Consumption of fuel/tonne of clinker 240 Kg
Average heat consumption : Kcal/kg clinker 1021
Size distribution of fuel : 20-24%, residue on 170 mesh ;
Whether coal feed rate is controlled Yes 3-4% on 72 mesh

10 Kiln Operation details

| | | | |
|---|---|---|---|
| Temperature of the shell in burning zone | 250-350°C | | |
| Measurement of the shell temperature | Radiation pyrometer: (i) Kiln shell temp :- | Normal | - 280°C - 300°C |
| Temperature of the flue gases | 330 - 360°C | Radiation | - 350°C - 400°C |
| Secondary air temperature | 900 - 950°C | Hot spot | - 400°C - 450°C |
| Frequency of (a) Without fuel | During power failure & ESP stoppage - (Monthly 5 to 6 times) | | |
| Kiln stoppage (b) Lower feed with fuel | 30-45% | | |

Shell ovality NCB-B

Frequency of measuring of ovality One year
Measuring the gap between tyre and kiln shell will be done in future
Metallic retaining rings and their position in the kiln. The length the flame and its position in the kiln whether auxiliary drive is available Not available / Yes

11 Refractory lining practice Lining with Wedge Bricks with Jack fixing. Use of two shape of wedge brick G20/420

11.1 Zoning of the rotary cement kiln

| Zone: | Drying | Calc. | Transition | Burning | Cooling | Discharge |
|---|---|---|---|---|---|---|
| Length, m | 23.4 mts. | 10.0 meter | 31.4 m | 3.113 | | |
| grade of refractories | $Al_2O_3$ 40% | 70% $Al_2O_3$ | 70% $Al_2O_3$ | 70% $Al_2O_3$ | | |
| Shape of bricks | Wedge Type | | | | | |
| Lining thickness | 200/230 mm | 200mm | 200mm | 230mm castable | | |
| Lining life | - | - | 70days | 9 months | | |
| Supplier of refractories | Silica-alumina | VRV Refractories, Madras. | | | | |
| | ~~Magnesitchrome~~ | And Shri Nataraj Ceramic and Chemical Industrial Ltd | | | | |
| | Insulating | ACC, Katrui, M P , Dalmia Puram | | | | |
| | Castable | | | | | |
| | Others | | | | | |

Lining Construction Ring / binding / Castable / Others

Combination of brick shape Only Wedge Brick G20/420

Kind of expansion joints Axial / radial No Expansion Joints for Brick Lining

Lining with mortor No

Admixtures to mortar used (water, chemicals)

Lining in dry way

Installation techniques used By Jack fixing

Heating/cooling schedules 25°C to 30°C raise per hours. Slow heating 24 h duration

Coating details : Length of coating, m 15 m
thickness 150-200 mm
Uniformity
stability Not much stable
nature (forous / hardmass) - Porous

Remark about type of wear/reasons : Coatingloss. Heavy

How do you analyse the performance of refractories in different zones Not analysed

Areas of frequent problems Burning zone especially in the bulged portion

Please give refractory lining charts

11.2 Preheaters, coolers, firing hood, burners A Refractories used in

45% $Al_2O_3$ 38% $Al_2O_3$ bricks for preheater

30% $Al_2O_3$ bricks for cooler

average refractory consumption per tonne clinker produced

11.3 Storage of refractories: Silica-alumina bricks In open yard
magnesitechrome bricks
castables, mortars In closed yard

11.4 Quality control measures adopted for selection of refractories.

Not available

ANNEX 4

1 **Name of the Plant & Address**

RAYMOND CEMENT WORKS,
GOPALNAGAR 495 663
DISTT: BILASPUR
MADHYA PRADESH

2 **Name and the designation of the technical staff** : A D KHATRI, M C AGRAWAL, R N VERMA

3 Incharge refractory section

R N VERMA

4 Capacity of the plant per year

1.25 Million tonnes

5 **Process** : Dry with Precalcinator

6 TECHNICAL DATA OF THE KILN

| Process | Capacity | Year of instal-lation | Supp-lied by | Kiln dim (Lxd) | Shell thick-ness mm | RPM | Type of preheater/ precal/ cooler |
|---|---|---|---|---|---|---|---|
| Dry with P C | 3850PTD | 1982 | FLS through L&T | 4.55M x 68.0 | 28mm and at tyre 50mm | 2.5 | FLS/ FLS Folax grate cooler |

7 Chemical composition kiln feed (%)

| LOI | $SiO_2$ | $Al_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | $SO_3$ | Cl | $Fe_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|
| 36.5 | 11.5 | 2.75 | 41.5 | 3.5 | 0.10 | 1.00 | 0.30 | - | 2,11 |

| AM | SM | LSF |
|---|---|---|
| 1.30 | 2.40 | 113.00 |

size distribution of the kiln feed

+172 = 18.5% +72 = 2.0%

8 Composition of clinker (%)

| $SiO_2$ | $Al_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | $SO_3$ | Cl | $Fe_2O_3$ |
|---|---|---|---|---|---|---|---|---|
| 21.00 | 5.70 | 62.50 | 3.00 | 0.20 | 1.40 | 0.40 | - | 3.5 |

| FREE CaO | $C_3S$ | $C_2S$ | $C_3A$ | $C_4AF$ |
|---|---|---|---|---|
| 1.50 | 45% | 22% | 9% | 10% as on 1.12.86 |

9 Fuel:

Ash content, % Max 42% Min 33% Average 36%

Chemical composition of ash, %

| $SiO_2$ | $Al_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | $SO_3$ | Cl | $Fe_2O_3$ |
|---|---|---|---|---|---|---|---|---|
| 22.00 | 8.80 | 2.00 | 0.30 | - | 0.40 | - | - | 26,55 |

Calorific value, kcal/kg 3600

Consumption of fuel/tonne of clinker 22%

Average heat consumption : Kcal/kg clinker 790

Size distribution of fuel 100 - 15% ; 72 - 2%

Whether coal feed rate is controlled Yes

10 Kiln Operation details

a/ Temperature of the shell in burning zone 180°C; transition zone - 245°C
Measurement of the shell temperature
b/ Temperature of the flue gases - 340°C
c/ Secondary air temperature -1000°C-1050°C
d/ Frequency of Kiln stoppage (a) Without fuel Once in a day
(b) Lower feed with fuel

e/ Shell ovality not tested

f/ Frequency of measuring of ovality
g/ Measuring the gap between tyre and kiln shell Measured during kiln stoppages
h/ Metallic retaining rings and their position About 470mm from the outlet sector
in the kiln. The length the flame and its position About 10M
in the kiln whether auxiliary drive is available Yes

11 Refractory lining practice

11.1 Lining of the rotary cement kiln

| Zone: | Drying | Calc. | Transition | Burning | Cooling | Discharge |
|---|---|---|---|---|---|---|
| a/ Length, m | 25 | | 15 | 20 | | 8 |
| b/ grade of $Al_2O_3$ refractories | 40% | | 70% | 70% | | 70% |
| c/ Shape of bricks | Wedge | | | | | |
| d/ Lining thickness Cam | | 200 mm | | 200 mm | | 200 mm |
| e/ Lining life | 2 years | about 8 months | | 6-8 months | | 1 year |

f/ Supplier of refractories
Silica-alumina M/s Natraj Ceramic and Chemical Industries Ltd., Kallakkudi
Magnesitchrome
Insulating M/s Natraj Ceramic and Chemical Industries Ltd
Castable M/s A C C Katni
Others

| g/ Lining Construction | Ring | binding | Castable | Others |
|---|---|---|---|---|
| | Yes | - | Vibrating | - |

h/ Combination of brick shape

i/ Kind of expansion joints Axial
radial Not providing

j/ Lining with mortor Nil

k/ Admixtures to mortar used (water, chemicals) Water

l/ Lining in dry way Yes

m/ Installation techniques used By brick laying machine

n/ Heating/cooling schedules 36-48 Hrs / 24-32 hrs

Coating details : Length of coating, m — About 18-20 M
thickness — 200-300mm
Uniformity — Uniform
stability — Stable
nature (Porous / hardness) — Hard

Remark about type of wear/reasons — Because of material abrassion, falling of coating due to stoppages

How do you analyse the performance of refractories in different zones — By Sp. consumption of refr.

Areas of frequent problems — Transition zone and Nose ring, burner pipe

Please give refractory lining charts

11.2 ) Preheaters, coolers, firing hood, burners ) Refractories used in

| | | | | |
|---|---|---|---|---|
| Fire bricks | 30-40% $Al_2O_3$ | | | |
| Insulating bricks | 60% Porosity | +55% | 55% | 90% |
| Castable | 30-40% | +90% | | |
| Cal silicate Blocks | Used | Used | | |

average refractory consumption per tonne clinker produced 1 kg in 1985

11.3 Storage of refractories: Silica-alumina bricks in covered storage
magnesitechrome bricks
castables, mortars

11.4 Quality control measures adopted for selection of refractories. Yes

ANNEX 5

WORK PROGRAMME OF MIROSLAV POTANČOK EXPERT FOR REFRACTORIES

DP/IND/84/020/11-20

Post title: Expert in Productivity Improvement through Selection, Installation, Use and Evaluation of Refractories in Cement Industry

Duration: Two months in the first mission

| Date | Activity |
|---|---|
| 23rd Oct to 22nd Nov 1986 | NCB Ballabgarh.<br>Discussions on the subject of improvement of refractory practice with NCB specialists, introduction to Indian cement industry, studying the problems of refractory materials used - their selection, testing and evaluation.<br>Lectures in refractory practice in cement industry:<br>- Increased lining life in cement rotary kiln system with special references to the application of basic bricks and refractory concreet.<br>- Refractory practice in cement industry. |
| 23rd - 26th November 1986 | Visit to Narmada Cement Ltd.<br>Dist. Amreli, Jafarabad 364 540<br>Gujarat.<br>Discussions with plant specialists, systemise and analyse the technical data and preparation of recommendations. |
| 27th - 30th November 1986 | Visit to Texmaco Ltd.<br>Dist. Cuddapah, Yerraguntla 516 309<br>Andhra Pradesh. |

| | |
|---|---|
| 1st - 3th December 1986 | Visit to NCB, research point in Hyderabad. Discussions with NCB personnel on the problems in Texmaco Ltd. plant. Lecture: Quality control of refractory materials by cement plant laboratories. |
| 4th - 7th December 1986 | Visit to Raymond Cement Works. Dist. Bilaspur, Gopalnagar 495 663 Madhya Pradesh. Lecture: Refractory practices in cement rotary kiln systems. |
| 8th - 16th December 1986 | NCB Ballabgarh. Systemise and analyse the technical data from cement plants with the assistence of NCB specialists in refractories. Preparation of report with findings and recommendations. Lecture: Installation and maintenance of refractory lining in cement industry. |

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