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PRODUCTIVITY IMPROVEMENT THROUGH CEMENT RAW MATERIALS TECHNOLOGY

DP/IND/84/020/11-03

INDIA

Third mission

Technical report : Study of problems related to cement raw materials, their evaluation, exploitation and use in selected Indian cement plants.

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

Based on the work of David P. Jefferson
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EXPLANATORY NOTES

<u>Usual technical abbreviations.</u>

1. Cement chemistry

S	=	SiO_2
A	=	Al_2O_3
F	=	Fe_2O_3
C	=	CaO
LOI	=	Loss on ignition
SR	=	$SiO_2 / (Al_2O_3 + Fe_2O_3)$
AR	=	Al_2O_3 / Fe_2O_3
LSF	=	$CaO / (2.8\ SiO_2 + 1.2\ Al_2O_3 + .65\ Fe_2O_3)$
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
IR	=	Insoluble residue
FL	=	Free lime

N.B. All the chemical analyses are on a weight percent basis.

2. Production abbreviations

tph	=	tonne per hour
tpd	=	tonne per day
tpy	=	tonne per year

3. Acronyms etc.

NCB	:	National Council for Cement and Building Materials
SP	:	Suspension pre-heater system
PC	:	Pre-calciner system
ESP	:	Electrostatic precipitator
OPC	:	Ordinary Portland cement
PPC	:	Portland-pozzolan cement
ACC	:	Associated Cement Companies Ltd.

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Ramasamyraja Nagar Cement Works (Madras Cements Ltd.)

Kota Cement Works (Shriram Fertilisers and Chemicals)

Siddhigram Cement Works (Cement Corporation of Gujarat Ltd.)

and their personnel for the assistance, co-operation, hospitality and fruitful discussions; the visits to the works were thereby made most successful.

ABSTRACT

Project : Productivity improvement through cement raw materials technology.

Number : DP/IND/84/020/11-03

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

Mission : Third. The first and second missions were undertaken by Dr G R Gouda in 1986 and 1987 respectively.

Duration : Six weeks, July to mid-August 1988.

Main conclusions and recommendations

Raw materials technology has not, in general, kept pace with advances in the design of cement plant. Modern suspension pre-heater and pre-calciner kilns are considerably more sensitive to variations in kiln feed and fuel than the older wet-process plants. Furthermore trace elements in the materials entering the system can cause major problems if the plant has not been designed to cope with them. Although there has always been a requirement for extremely careful raw material evaluation, planning and utilisation, this is even more necessary with modern plant. The design of a modern cement works requires a very detailed knowledge of the raw materials to be used and it is clear from a number of the plants visited that such information was not available to those who designed them; the result being major problems in the process control. With regard to the operation of the works, although there are exceptions, the overall impression gained is one of a lack of appreciation of the importance of

detailed raw materials planning and utilisation. This tends to result in variations in the feed and irregular quarry working, which could eventually lead to loss of reserves if the better stone is selectively removed. The variations in chemistry which result from poor utilisation of the raw materials will also result in instability in the kilns and other plant, causing loss of production due to down-time for removal of blockages or re-bricking. This problem is compounded by variation in the coal supplied to the kilns. Although high ash coal can be utilised in a cement plant, as long as appropriate raw materials are available, it is essential that it is of a uniform grade when supplied to the firing system and, where appropriate, the pre-calciner.

The major recommendations are as follows :

1. The standard of exploration, in particular the quality of borehole drilling, needs to be improved to ensure that good representative samples are obtained. This will ensure that the correct plant is installed at a works and that potential chemical problems are identified well in advance of being encountered.
2. There is a tendency for raw material assessment to use methods which are not particulary appropriate to cement raw materials. The assessment procedures used must not only be able to supply a complete chemical picture of all the raw materials present but also prove that the correct kiln feed can be achieved for the full life of the works.
3. Detailed quarry development plans are required for all raw materials. An overall quarry plan covering the life of a deposit must be established prior to confirmation of a deposit as a 'reserve'. A detailed five year quarry plan is essential in order ensure that the correct plant is available and access routes are developed well in advance. A very detailed one year plan is always required in order to identify chemical as well as logistical problems well in advance. This will ensure that arrangements can be made both in the quarry and at the works to deal with the problems before they occur, thereby ensuring that the plant operation is not affected.
4. In order to control the production of a continuously uniform kiln feed, it is necessary to sample the raw materials correctly at various points

from the quarry to the raw mill feed. The apparent lack of knowledge on both the theory and practice of accurate sampling must be rectified and the works equipped with appropriate sampling devices.

5. Since the coal used in the cement industry has a high ash content it contributes a relatively large amount of material to the final clinker, it must therefore be considered as a raw material. The blending and sampling of coal must be given the same priority as these functions are in the preparation of kiln feed. The quality of the fuel delivered to the works is normally beyond the control of the works' personnel, however if the cement industry is to function efficiently every effort must be made to ensure that the coal industry appreciates the absolute necessity for uniformity of coal delivered to a works, whatever the grade of the coal, and also to ensure that the grade of the coal is appropriate to the raw materials available to any given works.

CONTENTS

INTRODUCTION

This mission is the third in a series associated with the project aimed at "Productivity improvement through raw materials technology". A detailed description of the project is given in the report of the first mission, undertaken by Dr G R Gouda, entitled :

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

This mission, undertaken in 1986, was followed by a second in 1987 which was also undertaken by Dr Gouda. The report on this mission was issued in March 1987 under the title :

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

During the first two missions cement plants were visited and information was collected on the chemistry and properties of raw materials, preblending of raw materials, raw mixes, kiln dust and its applications, mineralizers, coal and coal ash, clinker quality, clinker absorption of the ash, burning process, flame shape and other operating parameters. On the basis of this data recommendations were given on such items as raw mix design, coal quality, flame shape, burner pipe and operational parameters.

The third mission followed a similar pattern except that the emphasis of the studies tended to be on raw materials evaluation, exploitation and handling, the preparation of kiln feed and the effect of the fuel used in the kiln. The various topics are discussed in depth in Chapter II of this report, 'Activities and Cutput'.

As the overall aim 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", experts from the NCB were also involved in the visits to the various cement works. In the case of the third mission these experts, two on each visit, were either geologists, mining engineers, chemical engineers or chemists.

I. RECOMMENDATIONS

The recommendations which follow are based on the observations made during the visits to the cement works and the discussions at the NCB. Full details of these observations are given in Chapter II of this report and the recommendations should be read in conjunction with these observations.

1. Every cement works should have a target kiln feed composition; this will be the same as the overall analysis of the raw materials reserves. The variation about this composition should be minimised; the aim should be a raw meal LSF variation of less than ±0.01.

2. Raw materials exploration must be planned on the basis of all the available information. Where there is an absence of information a 'worse case' situation must be assumed and the exploration carried out accordingly. For example the presence of harmful, soluble trace elements and soft or broken ground must be assumed (until proven otherwise) and the exploration techniques chosen accordingly.

3. Bulk samples taken for plant design must be representative, both chemically and physically, of the raw materials deposits. It is most unlikely that surface samples will ever meet these criteria and borehole core from wide diameter boreholes should be used for this purpose.

4. The only acceptable method of exploration borehole drilling for cement raw materials is core-drilling. No other method will provide the representative samples required. Core recovery should always be in excess of 96% and the choice of core-barrel diameter and flushing medium should reflect this. Under no circumstances should water be used as the flushing agent where soluble salts may be present (sampling the return fluid/sludge <u>is not</u> a valid method for detecting lost material). Under most circumstances a core diameter of less than

N-size (55 mm) is unsuitable, and where soft or variable material is encountered a core diameter of about 100 mm is preferred. Wide core is also essential if bulk samples are required for sending to equipment manufacturers; for this purpose the core should be cut in half using a diamond saw so that half the core remains for analytical purposes.

The number of boreholes and the spacing of those boreholes is determined by the structure and chemistry of the deposit. It is unlikely that any form of norm could be successfully applied to exploration drilling.

5. Accurate sample preparation is essential if the analyses resulting from sampling, whether during exploration or production, are to have any value. Samples must be comminuted to the correct size before sub-sampling is undertaken, and such sample splitting must be undertaken with rotary sample splitters or correctly sized riffles; under no circumstances should coning and quartering be used. Cleanliness is essential during sample preparation.

6. The aim of any cement raw materials investigation is to identify an area, or areas, which contain material with an overall analysis equivalent to the required kiln feed (allowing for modification by small quantiti of additives). It must then be shown that the distribution of material within these areas is such that it is possible, by economic extraction methods, to supply a continuous blend with the same kiln feed analysis for the total life of the deposit. Assessment of cement raw materials should only be undertaken by, or in cooperation with, those with a thorough knowledge of the industry. Wherever possible the simplest methods should be used. Where the variable nature of the chemistry results in computer assisted mathematical and statistical methods being appropriate, these should be used with extreme care. They should only be used by those who are both fully conversant with the mathematical techniques being utilised, and who also have an intimate knowledge of the deposit being assessed and the manner in which the sample data was obtained. It is most

unlikely that works personnel would have the required expertise to successfully use any computer package designed for raw material assessment and quarry planning.

7. Three quarry development schemes are required for every works. The first of these indicates the manner in which the complete reserve will be worked so as to always supply the correct grade of stone. The second, the five year plan, indicates in detail the medium term quarry development and ensures that access roads, relocation of such items as power lines, and purchase of plant are planned well in advance. The one year plan is designed to identify the short term chemical and logistical problems which may affect the day to day running of the cement works. This will enable the quarry and plant staff to work together to minimise the effect of such problems.

8. Quarry development must take into account the fact that there are monsoonal periods. The mix of stone taken from the quarry must not change with the seasons as this will cause instability and potential major problems on the works. Quarry floors should slope away from the working faces and sumps equipped with pumps should be provided where necessary.

9. The production of kiln feed must be considered as a continuous and integrated process involving both the quarry and the works. The variations which are encountered in raw materials can be divided into different types, short term variations which are smoothed in the homogenization silos, those with of medium term which are handled in the blending bed, and finally the variations with a longer frequency which are removed by correct quarry planning. The output from any one of these stages is the input to the next, resulting in an intimate connection between all the blending activities. It is essential therefore that the quarry and works personnel work as a single team in the production of kiln feed.

10. Sampling of dust and chippings from blast-holes should always be practiced in order to maintain control over the stone sent from the quarry to the works. The preferred method of sampling is to use a rotary sample splitter beneath a dust suppression unit of the type which collects all the material from the drill-hole.

11. An automatic sampler should always be installed prior to the blending bed in order to ensure that it can be constructed accurately to a pre-determined analysis. Hand sampling at this point is not adequate. Of the various types of automatic samplers on the market the swinging arm sampler (Annex 4) is recommended. The frequency of sampling should be determined by experiment but is unlikely to be less than once every five minutes, every two minutes not being uncommon; hourly composites are made up from these samples. Sub-splitting can be done by hand, the sample from the automatic sampler being crushed in a laboratory-sized hammer mill and reduced in mass using rotary sample splitters or, if these are not available, correctly sized riffles.

12. Where raw materials consist of a mixture containing a range of grain sizes they should not be allowed to fall freely for any distance, since this will lead to segregation. Silos and hoppers should be kept full and the stackers used on blending beds should remain within a few centimetres of the top of the bed. Where there is a danger of segregation in blending beds or stockpiles a windrow method of stacking should be used.

13. The fuel supplied to any cement works must be suitable for its raw materials; specific collieries should be matched to individual cement plants. Dry-process works which have a primary limestone source with a silica content of less than about 8% may be able to produce a high quality clinker using coal with an ash content of up to 35%. However at those works where the limestone contains about 12% silica the maximum permissible ash content is about 30%. On those works using the wet-process it is unlikely that coal with more than 30% ash could

ever be successfully utilised if an acceptable product is to be manufactured.

14. All cement works require coal blending facilities. Moreover the coal delivered to the works must not vary outside the limits imposed by the blending facilities and sufficient coal must be delivered to the cement works to ensure that the blending facilities can be used.

15. Staff in the quarry and at the works must work together as a team. This would be facilitated by having a Raw Materials Manager, with a similar status to the works Technical Manager, rather than a Quarry Manager. A management team of high caliber is often essential if the raw materials deposits are to be worked correctly. It is essential that quarry personnel understand the cement making process, and therefore the reasons for quality and chemical control in the quarry. It is also essential for works personnel to understand the complexities of raw materials extraction. Training courses are a valuable aid to achieving this objective and the NCB should consider developing these.

16. Although highly qualified and very competent, the NCB staff involved in raw materials technology lack, in general, the practical experience necessary to identify and solve basic raw materials problems. The practical answer to unsatisfactory kiln feed chemistry or variations in raw materials is often found by modifying quarrying practices or adding screening plant, rather than by developing new types of cement or applying complex computer procedures to the problem. There are no texts or training courses for teaching this type of problem solving. It is essential that the NCB staff are exposed to the works problems, actually on the works and in the quarries, as often as possible. Discussions with works' personnel are not sufficient, a 'hands-on' approach must be applied.

II. ACTIVITIES AND OUTPUT

A. Job description and objectives of the activity

As detailed in the Job Description (Annex 1) the overall aim of the project is "to improve the total productivity factor in the industry and the technological levels of the various units in the cement industry in India through strengthening of the national centre - the National Council for Cement and Building Materials (NCBM)".

The third mission of six weeks, from July 4 to August 14 1988 inclusive, concentrated on raw materials aspects of the industry. The objective of this mission, as defined by the NCB, was to :

> "strengthen the existing capabilities of NCB in productivity improvement through raw material technology. The area of approach embodies suitable matching of raw materials characteristics of various raw materials and fuels in order to obtain good quality clinker out of lower grade limestone and coal in selected cement plants, study of problems related to intricacies of raw material deposits and their exploitation. In addition, study of the variations in chemical and mineralogical characteristics causing instability in blending systems/kilns is also envisaged. It is expected that through effective interactions with NCB in strengthening the expertise in raw materials technology by effectively diagnosing technological problems and productivity constraints, formulating programmes and methodologies for solving the technical problems and improving productivity."

B. Technical activities

The objectives were achieved by means of visits to four cement plants using a range of raw materials, together with discussions and the presentation of two lectures at the NCB. The programme schedule is given as Annex 2. At each cement works all departments were visited and intensive discussions with management on the subject of raw materials related problems were held. Wherever possible suggestions were made as to the method of approach which should be used for solving these problems. On some works a presentation was given on the subject of raw materials and raw materials control and technology. Following each visit a report was prepared and these are included herewith as Annexes 5 to 8.

The two lectures presented at NCB both covered all aspects of cement raw materials technology from exploration to clinker production. The first, presented early in the mission looked at the problems from a theoretical point of view. The second talk was given at the end of the mission and considered the practical problems of raw materials technology in the light of the visits to the various works.

C. Observations, findings and comments

The following sections cover all aspects of cement raw materials technology and contain the observations made on these subjects during both the works visits and the discussions at the NCB. The recommendations made in Chapter I of this report are based on these observations.

General statement.

A cement plant consists of a series of relatively simple reaction vessels which, on the whole, are designed to carry out a pre-determined function on a material of known composition. Should the composition of the material fed to these reaction vessels vary very much from the design parameters it is unlikely that they will perform correctly or efficiently. Furthermore the flexibility accorded by the process control of the cement plant is such that very little modification can be made to the final product by alteration of parameters such as residence times or rate of feed of raw materials or fuel. Thus the quality and consistency of the final product, the cement, is largely controlled by the quality and consistency of the raw materials supplied to the process. Since variation in feed can also cause operating problems, the maintenance of the plant, and therefore the cost of production, are also affected by the nature of the raw materials.

The chemical composition of the kiln feed will control to a large extent the quality of the clinker. For an acceptable product the composition of the raw mix must have a precise composition. Moreover this composition should not vary; every works should aim to minimise the kiln feed variation to less than ±0.01 of the target LSF. The raw materials which are used to produce the kiln feed will vary widely in their chemical composition and it is the purpose of raw materials technology to reduce this initial variation in a planned manner down to the level of variation acceptable to the plant. This could be considered the most important task on a cement works since, once the kiln feed has the correct composition and minimal variation, the processing plant should run efficiently and continuously producing a uniform clinker.

The key concept in the correct use of raw materials is planning, this in turn requiring a thorough knowledge of the quality of the raw material available at any time. Much of raw materials technology is therefore involved with accurate sampling, be this at the exploration stage or during production.

Exploration.

The amount of exploration which can be undertaken for cement raw materials always tends to be limited by financial considerations. However as a rough guide it is suggested that an exploration expenditure equivalent to about 0.5% of the total capital cost would be appropriate in the case of a new works project. The various stages in cement raw materials investigations have been detailed in the published literature (e.g. Jefferson 1978, 1983), however certain points need to be emphasised in the context of the Indian cement industry.

1. Initial background studies. It is essential that all the available information on a target area is studied prior to starting a raw materials investigation. The aim of any exploration for cement raw materials is to determine the configuration, chemistry and variation in chemistry of the potential deposit(s). In order to do this accurate sampling must be undertaken. Only by detailed literature and field studies can the correct method of sampling be determined. This may be by pitting or borehole drilling. In the latter case the size of core and drilling fluid to be used must be determined prior to the project starting. For example in coastal areas where relatively young deposits are to be investigated, for example the coast of Gujarat, studies of the published data will invariably indicate that soluble materials such as salt or gypsum are likely to be encountered. In such instances it is essential to specify air as the borehole flushing medium before the exploration commences; failure to do so may well result in problems once the works is operational, as it may well do at Siddhigram cement works.

2. Sampling for equipment design purposes. Most cement works plant is designed or chosen on the basis of samples collected from the raw materials deposits. It is absolutely essential that such samples are both chemically and physically representative of the materials to be used in the process. There is considerable evidence from all the cement works visited of unrepresentative samples having been sent to manufacturers. The results range from a lack of screening facilities (causing blockages and incorrect raw material chemistry) to an absence of gas bypasses (to prevent cyclone blockages caused by volatile compounds). The most suitable material for supplying to manufacturers

for design purposes comes from wide diameter borehole core obtained during exploration. Large diameter drilling also enables the core to be split, using a diamond saw, to allow half the core to be retained for analysis. Surface samples are rarely, if ever, suitable for design purposes.

3. Drilling. Observations 1 and 2 above have indicated two reasons for a very high standard of borehole drilling. It is absolutely essential that the samples obtained from boreholes are of the very highest standards since :

   a) Determination of the suitability of the material as a cement raw material is almost entirely dependant on the samples.

   b) The chemical and physical variation of the material must be accurately known so that the continuous economic extraction of material, of the correct chemistry, for an adequate period of time can be proved.

   c) The correct design of the cement plant is dependant upon the samples obtained.

   It is essential therefore that core-drilling is used during exploration since there are no other forms of borehole drilling which can be shown to give representative samples. Moreover core recovery of less than 96% per metre is unacceptable. Wide diameter core of about 100 mm is also recommended especially for soft or variable materials; core of less than N-size (55 mm) is rarely acceptable for cement raw materials investigations. The type of drill-bit and the nature of the flushing medium (air, water or foam) must be appropriate to the type of ground to be encountered. Some details of modern drilling equipment are given as Annex 3. Good recovery of soft partings is essential since it is often these that contain potentially harmful trace elements; they also tend to cause handling problems in the plant. Evidence of inadequate borehole core recovery, in the form of materials handling problems and un-anticipated chemistry, were noted to a greater or lesser extent at all the works visited.

The number of boreholes required and their distribution on the ground is a function of the structure and chemistry of the deposit. It is not considered feasible or practical to set cut norms for exploration since every deposit will have its own characteristics. Borehole drilling serves two purposes, firstly to determine the structure of the target deposit, and secondly to provide samples so that a three dimensional chemical picture of the deposit can be built up. The distribution of boreholes for the former purpose will be determined by the geology of the deposit, the boreholes drilled for the chemical data will be dependant upon the chemical variation and the distribution of the structural boreholes which will also have been sampled. Although the use of sampling grids is advantageous this is normally only practical on relatively horizontal strata in areas of subdued topography. The grid spacing cannot normally be predicted and the usual practice is to start with a wide rectangular grid of between 500 m and 750 m spacing and reduce the spacing on the basis of the results obtained; the final grid may not be uniform over its whole area, nor need it remain rectangular if trends or different rates of variation are found in the deposit.

4. <u>Sample preparation of exploration samples and production samples.</u> All raw materials samples tend to be large and coarse grained. It is necessary therefore to reduce the sample both in grain size and volume so as to produce an analytical sample. If this is not done correctly and accurately the result of the analysis, together with the action taken on the basis of that result, will be in error. Evidence from the various works visited suggests that the importance of this aspect of sampling is not appreciated. It is essential that the grain size of samples is correct before they are subdivided. A guide to the relationship between grain size and sample size has been given by Gy (1979) who states that :

'sample weight in grams should be greater than 125,000 d^3

- where d is the maximum particle diameter in cm.'

Thus it is necessary to crush all borehole core (or works raw material sample) to less than about 2 mm before the mass of material can be reduced to about 250 gm. Sub-splitting of all samples should be performed with rotary sample splitters where possible, although correctly sized riffles are acceptable if used carefully. The sizing of a riffle is based on the size of material to be passed through it. The number of chutes should not be less than about 15 and the width of the chutes in millimetres should be equivalent (2 d + 0.5mm), where d is the maximum particle diameter in millimetres. Under no circumstances should coning and quartering be used for reduction of sample size. Cleanliness is also important in sample preparation. All equipment, including laboratory crushers, should be brushed clean between samples within a batch, and should be thoroughly cleaned between batches. The cleanliness of the sample preparation facilities on the cement works is an area which requires some improvement. The various aspects of sampling have been covered in depth by Gy (1967, 1971, 1975, 1979).

5. Assessment of exploration data. The aim of any cement raw materials investigation is to identify an area, or areas, which contain material with an overall analysis equivalent to the required kiln feed (allowing for modification by small quantities of additives such as iron ore). It must then be shown that the distribution of material within these areas is such that it is possible, by economic extraction methods, to supply a continuous blend with the same kiln feed analysis for the total life of the deposit. It is not sufficient to merely prove that a deposit has an analysis, or range of analyses, which make it "directly usable without beneficiation for manufacture of ordinary portland cement and other cements based on ordinary portland cement clinker", or "likely to be made suitable for blending or direct use for manufacture of ordinary portland cement by upgrading" (Cement Research Institute of India, 1981).

Most cement raw materials deposits tend to show patterns and trends. It is the purpose of the assessment to determine these features and use them to construct a total chemical model of the deposit(s), so that best estimates of grade can be made for all and every part of the reserve. Experience has shown that the best results are frequently obtained by using the simplest methods possible. Manual methods are frequently successful since the experience of the geologist, mining engineer or chemist can be incorporated into the assessment in a way which is impossible in automated methods which are based on purely mathematical procedures. In complex deposits however modern computer assisted techniques such as geostatistics can play an important role (Jefferson, 1987a, 1987b). Due to the frequently complex chemistry of cement raw materials deposits it is not normally possible to enter borehole and sample data into an assessment package and accept the output at its face value. Just as with manual methods, the data must be frequently interpreted by the raw materials specialist and different automated techniques may be required for different parts of a deposit, with a manual adjustment in those areas where techniques overlap. Thus assessment using advanced computer aided methods must only be employed by personnel who are not only experienced in the mathematical techniques being used, but who also have an intimate knowledge of the deposit being assessed and the manner in which the data was obtained. It would be extremely unwise for works personnel to attempt to utilise any of the commercial packages (or any other packages) which are available to assess the works raw materials or develop quarry plans.

Extraction of raw material and its preparation for kiln feed.

There is still a tendency in the cement industry to consider the quarries as suppliers of stone from which the plant will make cement. Although this approach may work where raw materials are uniform (although it should still not be adopted), it will not work where a high degree of variability exists in the material or where the grade of stone is low. In common with many other parts of the world where the cement raw materials are a mixture of very old and relatively recent deposits, the variation and grade of the materials in India are such that the correctly planned extraction of the raw materials is essential if the quality of the product is to be acceptable and uniform. Good quarry planning is vital, but appears to be lacking at many plants. The following points were identified during the visits to the various cement works as being particularly important.

1. Quarry development plans. If the raw materials assessment has been undertaken correctly it will have been possible to draw up a relatively detailed quarry development scheme for the complete life of the deposit. This will not only indicate those areas have to be worked simultaneously to yield materials which can be blended to yield kiln feed, but will also ensure that other developments in the reserve area do not create long term problems. Failure to undertake this basic planning step has resulted in one of the works which was visited building employee housing on top of limestone reserves, in a position which should be the centre of a future quarry. The second planning stage is that of the five year plan. These plans will detail the progressive development of faces for the next five year period and ensure that such items as the access roads are developed correctly, that budgeting for new plant is undertaken well in advance, that items such as power lines or roads which have to be relocated are identified early and so on. The most detailed of the necessary plans is the one year plan. The purpose of this is to identify potential chemical and logistical problems which could affect the day to day running of the works. This will enable the quarry and works staff to work together to plan the action which will be required to overcome these short term problems.

2. Climatic variations. Quarry development planning should take into account seasonal variations in climate. The mix of components should not change during the monsoonal periods since this will lead to instability within the kiln system. There would appear to be no problems in ensuring that quarry floors slope away from the working faces, or channels and sumps with pumps are provided to cope with the seasonal rainfall. This is normal practice in all areas which suffer from continuous or seasonal rainfall.

3. Blending. The aim of the quarry development schemes is to work the raw materials deposits in such a way as to reduce the natural variation to a level at which the plant on the works can produce a constant kiln feed with an acceptable minimal variation. Raw materials variations can be divided up on the basis of the time over which they operate. Those variations with a frequency of a few hours can be smoothed in the homogenisation silos after the raw mill. Those variations with a frequency of a few days can be removed in a blending bed, whereas variations occurring on a time scale greater than this have to be removed in the quarry. The preparation of kiln feed can therefore be seen to be an integrated process involving both the quarry and the works and must always be treated as such.

4. Quarry sampling. The stone despatched from the quarry can only be allowed to vary within the limits to which the blending bed and homogenisation silos were designed. The exploration data only provides best estimates of the grade of blocks, perhaps 100 metres square. The variance of these best estimates may be greater than the allowable variation in ex-quarry stone. It is frequently necessary therefore to determine a more accurate estimate of the stone to be worked. This is best done by sampling the blast-hole chippings. The preferred method of performing this task is to utilise dust suppression units on the quarry drill-rigs which collect all the material from the drill-holes. A rotary sample splitter can then be located beneath the outlet from the dust suppression unit allowing a relatively accurate sample to be obtained. Analysis of each drill-hole sample, or group of samples, will give an overall analysis for the block before it is blasted and will also indicate any variation within the block. A knowledge of the chemical variation within a blast will allow face blending to be undertaken by moving the excavator during loading. If shot-hole drilling is undertaken well in advance of blasting, information may be available on two or more blocks, thereby giving a choice of which one to blast in order to provide the most appropriate chemistry for the blending bed.

5. Sampling of crushed stone. Knowledge of the grade of stone contained in a quarry blast enables feed-forward control of the supply of stone to the works blending bed, which should be constructed to a precise target grade. However the quality of the sampling information from the quarry is not accurate enough to control the exact quantities of the various grades of stone which are required to produce a blending bed of precisely the required composition. It is essential that sampling of the stone being fed to the stacker takes place to enable the bed to be constructed with this required chemical composition. Such sampling does take place on many works, however there are indications that the standard of this sampling is frequently completely inadequate. Hand sampling as practiced at a number of locations is not only inaccurate, it could also be misleading. Automatic samplers are essential for accurate sampling of bulk materials. Many automatic samplers are available, a large number of which are unfortunately as inaccurate as hand sampling. The only automatic sampler encountered during the works visits fell into this category. The only accurate method of sampling a stream of lump stone is to take a complete section out of this stream. The preferred method of carrying this out is by means of a swing arm sampler which passes a bucket through the stream where it is falling at a discharge point. The Birtley sampler is an example of this type of arrangement. Annex 4 contains details of swing arm samplers. The frequency of sampling is best determined by experiment; it is unlikely to be less than once every five minutes and is often as frequent as once every two minutes. These samples are combined to give hourly composite samples. Sample reduction can be undertaken automatically, and many manufacturers can supply plant to do this. However such equipment is expensive, complex and requires a high level of maintenance. It is recommended that manual preparation using a laboratory sized hammer mill and rotary sample splitters, or correctly sized riffles, can be undertaken at the sampling station.

Installation of a sampling point prior to the mill or mill-feed hoppers will enable positive feed-forward control of the material to the raw mill to be accomplished. Sampling at this point can be of value when a multi-component mix is used, or if the chemistry of the blending bed is not known precisely.

6. Material segregation. Raw materials tend to consist of both coarse and fine particles. It is not uncommon for the different grain sizes to have different chemical compositions. It is essential therefore that segregation is avoided. Allowing raw materials to fall through large distances onto stockpiles, into silos or at transfer points is a major source of segregation. In order to avoid this problem every effort should be made to minimise the distance materials fall transfer points, silos should be kept full and stacking booms should discharge only a few centimetres above the top of piles. Where there is a great difference between the maximum and minimum particle sizes, or where the grain size distribution is bi-modal, windrow stacking rather than chevron should be used for blending-beds.

Fuel and kiln feed design.

Although coals with a range of qualities occur in India it is national policy to utilise the better grades in the steel and power industries and supply the poorer grade material to the cement industry. In general terms this is clearly a realistic method of using the countries resources since the cement industry is capable of utilising high ash coal. However there is considerable variation both in raw material quality and process type throughout India, and if low-grade fuel is to be supplied to the industry, this supply requires considerably more control than at present. Even on a modern dry-process works the quantity of ash incorporated into the clinker can be about 4.5% of the kiln feed, and in the wet process this figure can approach 6%. The chemical influence of the ash is therefore potentially very great. The fuel must therefore be treated as a raw material. It is essential that the criteria of target grade and uniformity which are applied to the raw materials, are also be applied to the coal. Variation in the coal will lead to variation in the quality of the cement and to problems in the running of the plant; this is especially true on plants equipped with PCs since these are designed to operate efficiently only with a uniform fuel as well as a raw meal of constant composition. The build-ups in the cyclones and on the ID-fan at Satna are almost certainly due to variable coal chemistry, and the variable nature of the fuel has probably contributed to the breaking in half of the kiln at Madras Cements Ltd. as well as the burning out of the bricks at Kota.

The potential problems which can be caused by high ash, and especially by variable high ash coal, can be illustrated by a consideration of the chemical reactions in the kiln. The parameters upon which the kiln feed (and the composition of the clinker are based) are LSF, SR and AR. The LSF can be considered as governing the proportion of silicates present. Theoretically an LSF of 1.0 gives the maximum C_3S content in the clinker. If the LSF of the final mix (i.e. raw meal plus ash) is above 1.0 no amount of hard burning will reduce the free lime to 2%. A high LSF makes combination difficult, but since it maximizes the C_3S content it produces a cement with good strength development. The silica ratio determines the amount of flux present. A low SR gives more flux than a high one, however the latter gives more silicates and, at constant LSF, this would mean more C_3S. A low SR produces a good burnability due to the high flux, however it results in low silicate content, a low C_3S to C_2S ratio with resulting low strengths. The alumina ratio governs the quality of the flux, the higher the ratio the more viscous the flux since more aluminous melts have a higher viscosity than iron rich ones. The AR also determines the rate of development of flux. It is minimal at an AR of 1.38 but increases above or below this value. As C_3S formation occurs in the burning zone, whereas C_2S is formed prior to this, and early flux formation will absorb C in the form of C_4AF at low alumina ratios and C_3A when the AR is high, a value of about 1.38 will optimise the C_3S potential of the mix. Bearing these factors in mind it can be seen that in plants using high ash fuels the nature of the reactions taking place in the mix of high LSF which is fed to the kiln will change rapidly when they encounter the ash near the burning zone. The nature and quantity of flux and the equilibria in the mix will suddenly become unbalanced since the new chemistry will dictate a different reaction equilibrium. If the raw material and fuel are always constant good kiln control will probably be able to stabilize this change in conditions. However any variation in the materials could well result in uncontrollable conditions and the formation of build-ups and/or rings. Uniformity of both kiln feed and fuel are therefore essential.

The specific observations on kiln-feed design and fuel are as follows :

1. The relationship between raw materials and fuel. Since ash is absorbed into the clinker, the use of high ash coal to produce a good OPC clinker requires that the kiln feed has a very high LSF. This in turn means that high-grade (low silica) limestones have to be used for the production of the kiln feed. Unfortunately, although high-grade limestone does occur in India, much of the limestone has a relatively high silica content. The use of high ash coal can therefore conflict with the production of high quality cement. The reduction in LSF from kiln feed to clinker caused by the fuel is about 3-4% for each 1% of ash on raw meal; in the case of the wet-process this can be as high as 6%. Thus the use of high ash coal in a wet-process works with a limestone component containing about 12% silica almost certainly precludes it from manufacturing a high quality clinker. It is impossible to put forward a general theory as to which grade of limestone is best suited to which coal, since the silica, alumina and iron in both the limestone, the secondary materials and the fuel all vary widely. However it is considered that, in very general terms, those mixes where the primary component is a limestone whose silica content is about 12%, can rarely, if ever, produce a high quality cement if the ash content of the coal is in excess of 30%. If the silica content of the primary limestone is less than about 8% it may be possible to produce an acceptable clinker with a coal ash content in the fuel of up to 35%. All these figures relate to the dry-process. It is unlikely that coal with an ash content in excess of 30% could actually be successfully used in a wet-process kiln except with almost pure, chemical grade, limestone.

2. Choice of coal. It is necessary therefore to match the coal from the various collieries with the appropriate cement works if the latter are to produce a cement of acceptable international standard.

3. Uniformity and supply of coal. Since the coal ash plays such an important part both in the quality of the final product and in the smooth running of the plant, especially the kiln, it is necessary to ensure that the coal is blended to a uniform target composition prior to its utilisation. All cement works require coal blending facilities. Moreover the coal delivered to the works must not vary outside the limits imposed by the blending facilities and sufficient coal must be delivered to the cement works to ensure that the blending facilities can be used.

Management of the process.

Although the attitude varies from works to works, there is still a tendency to consider the quarry as a supplier of material to be used for the manufacture of cement on the works, rather than consider the quarry as an integral part of the process. This latter, correct attitude can only come about when the caliber of the personnel in the quarries is equal to that on the works. Those in charge of winning and blending the raw materials to a level which can be accepted by the works must be considered as Raw Materials Managers and have a similar standing to the Technical Managers on the works themselves. All the management team, whether in the quarry or the works must have a thorough knowledge of the chemistry and technology of the cement making process. Technology training for all personnel is essential. The role of the NCB in this is extremely important. Although they offer, through the Centre for Continuing Education and Human Resource Development, an impressive range of training courses the distinction between quarry and works is maintained. The only courses currently listed as being specifically aimed at quarry personnel are on the environmental impact of quarrying (course STC-1/88) and advances in quarrying practices (course STC-2/88). The main course for production and process managers, Cement Technology for Senior Executives (course STC-3/88) lists 'Advances in limestone exploration and mining methodologies' as the only raw materials content of the course; a potentially theoretical rather than practical approach to the problems faced by the works themselves. However the cement technology courses for foremen (STC-4/88) and non-technical personnel (STC-5/88) list 'Raw materials, their technological assessment and effect on various unit operations' and 'Raw materials and their quality requirements' respectively in their course contents. Development of these latter two themes on the higher level courses could well be advantageous. It is essential that quarry personnel understand the cement making process, and therefore the reasons for quality and chemical control in the quarry, and it is also essential for works personnel to understand the complexities of raw materials extraction and therefore the need for long term planning.

The training and development of NCB staff in raw materials technology.

Works personnel generally have limited experience in raw materials, quarrying, mobile plant, handling problems and so on. Unlike many plant problems which can be solved with the help of the plant manufacturers, or which may occur on many works and therefore become the subject of papers and articles in the cement literature, raw materials problems tend to be looked upon by works personnel as their own unique special difficulties; this is rarely the case. The NCB is however in a unique position to gain experience from quarries and plants throughout India, and elsewhere, and therefore assist in solving problems at individual works. In order to do this however the appropriate personnel at NCB must first obtain experience in as many operating plants as possible; there is no substitute for working on the works and in the quarries solving the problems, carrying out the sampling and undertaking the tests themselves. There is no doubt that the caliber of the staff involved in raw materials technology at NCB is very high, however it could be considered that the emphasis of some of the work being undertaken is rather academic and premature. The problems of crushers blockages, flooded quarries and cyclone blockages are problems for which help is needed today. The development of computer programs for quarry development may be of value in the future but is not required at the present time; it is also pertinent to note that such computer software has been freely available throughout the world for some time and has proved to be of little value to the industrial minerals industries except in very special cases.

There is also an approach to problems, observed both on the works and to a certain extent at the NCB, which can aggravate a situation rather than solve it. It was noted that rather than solve actual problems, it was the symptoms of the problem which were being treated. This approach is perhaps typified by the way in which raw materials problems have been handled both at Madras Cements and at Kota cement works. In both instances the works were designed with simple mixes, however the chemistry of the materials received at the works changed from the design parameters. Rather than solve the problem of why the chemistry had changed, both works tried to treat the symptoms by importing a vast range of raw materials in an attempt to modify the mix chemistry. The result in both cases is variation in kiln feed which causes considerable problems. The NCB's work on active belite cement can be seen, to a certain extent, to be a reflection of the same approach. It is claimed that this type of material may offer the possibility of manufacturing a form of cement using low-$CaCO_3$ limestone and low-calorific value, high-ash fuels, as well as MgO-rich materials (see summary by Stark and Müller, 1988). A more practical approach to the problem would be to determine, for example, why a material is low grade. It may be, as noted at Satna, Kota and Gujarat, due to clay which can be removed by screening, a cheaper and more practical solution to the problem. The high-technology answer may be more impressive, but the simple answer if often the most practical and effective one. More practical involvement on the works by NCB personnel could well strengthen this very basic problem solving requirement.

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Annex 1

31 August 1987

UNITED NATIONS

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

UNIDO

PROJECT IN THE REPUBLIC OF INDIA

JOB DESCRIPTION

DP/IND/84/020/11-03

Post title Expert in Productivity Improvement through Raw Materials Technology

Duration Six weeks (return mission)

Date required As soon as possible

Duty station New Delhi, with extensive visits to cement plants and with the possibility of travel to other NCBM-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 National Council for Cement and Building Materials (NCBM).

Duties The expert will be attached to NCBM as a part of the international team led by the Project Director, and will work under the supervision of the Council's Chairman and Director General.

Whilst the field of work of the expert will cover the entire spectrum of activities relating to Raw Materials Technology, the special thrust will be in the following areas:

First Mission : Raw mix design and burnability studies in selected Indian Cement Plants.

Subsequent Missions : Suitable matching of raw material characteristics of various raw materials and fuels in order to obtain good quality clinker out of lower grade limestone and coal in selected cement plants investigation on the use of mineralisers in cement manufacture.

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

a) Effectively diagnosing technological problems and productivity constraints;

..../..

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

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

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

To enable it, in cooperation with the industry, to achieve increase in capacity utilization, reduction in power consumption, reduction in dust emission, reduction in kiln down time and establish a central data base at NCBM 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 which might be taken.

Qualifications: Chemist/Technologist or Engineer with at least 20 years of extensive experience including adequate experience at responsible and senior levels in Raw Materials Technology in the cement industry. 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.

Language: English

Background Information: Today the cement industry in India comprises 94 plants - having a total annual installed capacity of 36.5m tonnes. The raw materials specially the limestone available to the Indian Cement Plants are generally of poor quality with high silica and Magnesia content. The coal also has very high ash content of the order of 40% even higher than requiring a judicious matching of the various raw materials component.

The National Council for Cement and Building Materials (attached to the Ministry of Industry, Government of India) is the national centre devoted to Research Technology Development and Transfer, Education and Industrial Services; 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

PROGRAMME SCHEDULE

Activity	Date
UNDP Mission formalities	08 July 1988
Briefing by the Project Director and Chairman and Director General, NCB	11 July 1988
Discussion with Director, NCB	11 July 1988
Discussion with NCB officials on aspects of computer aided evaluation of cement raw materials	12 July 1988
Visit to Satna Cements, Madhya Pradesh	13 July 1988
Interaction with plant personnel on problems related to raw materials and their process, exploration and exploitation of raw materials deposits	14-15 July 1988
Return to Delhi	16 July 1988
Interaction with NCB counterparts and preparation of visit report	18-19 July 1988
Visit to Madras Cements, Tamil Nadu	19 (20) July 1988
Interaction with plant personnel on problems related to raw materials and their process, exploration and exploitation of raw materials deposits	21-23 July 1988
Return to Delhi	24 July 1988

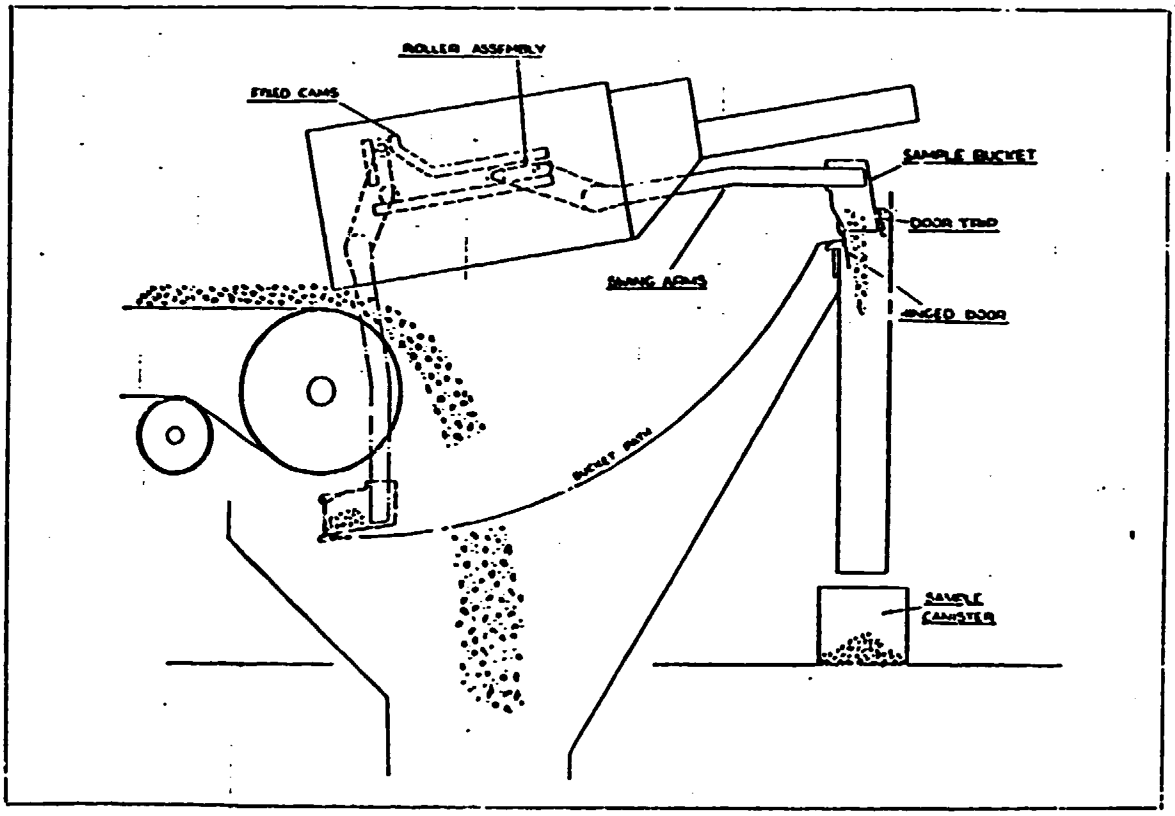
Interaction with NCB counterparts on various aspects of Raw Material Technology based on plant visits. Preparation of visit report	25-26 July 1988
Present lecture : Raw Materials Technology - Theory	27 July 1988
Visit to Shriram Cements, Rajasthan	27 July 1988
Interaction with plant personnel on problems related to raw materials and their process, exploration and exploitation of raw materials deposits	28-29 July 1988
Return to Delhi	29 July 1988
Visit to Cement Corporation of Gujarat, Gujarat	01 August 1988
Interaction with plant personnel on problems related to raw materials and their process, exploration and exploitation of raw materials deposits	02-04 August 1988
Return to Delhi	05 August 1988
Interaction with NCB counterparts and preparation of visit report	08-09 August 1988
Present lecture : Raw Materials Technology - Practice	09 August 1988
Discussions on the outcome of the mission and finalization of the mission report. Debriefing with Project Director.	10-11 August 1988
Depart Delhi	12 August 1988

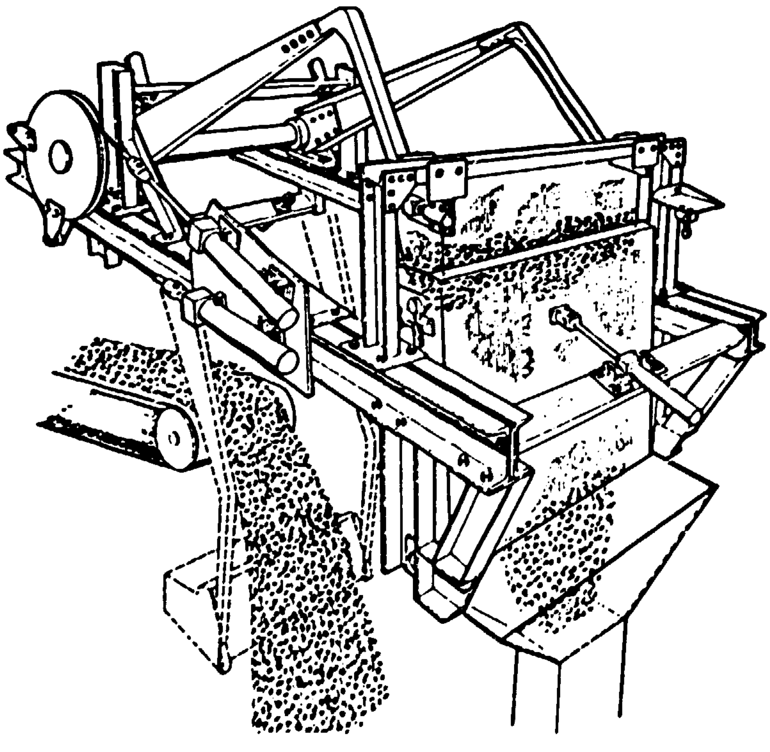
Annex 3

DIMENSIONS OF SOME ROTARY DRILLING EQUIPMENT

Core barrel design	Core bit OD (mm)	Core diameter (mm)
NWG, NWF, NWM	75.3	55
NWT	75.3	59
HWF, HWG	98.8	76
HWT	98.8	81
PWF	145.4	92
SWF	145.4	113
UWF	173.7	140
TNX	75.3	61
HWAF (air flush)	99.5	71
412	105.2	75
T6	76.0	57
T2	76.0	62
T6	86.0	67
T2	86.0	72
T6	101.0	79
T2	101.0	84
T6	116.0	93
T2	131.0	108

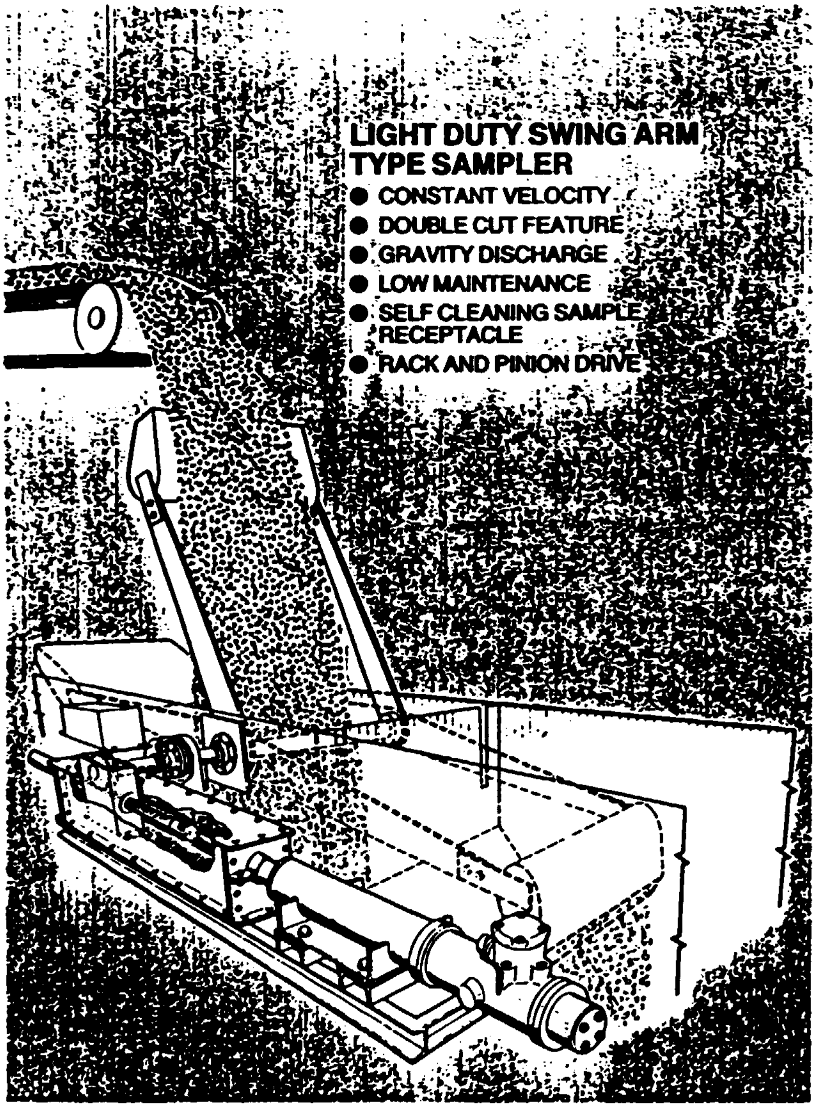
RAW MATERIALS SAMPLERS





TILT HOPPER SWING ARM SAMPLER

- CONSTANT VELOCITY
- SINGLE OR DOUBLE CUT FEATURE
- ELEVATED DISCHARGE
- LOW MAINTENANCE
- SUITS LARGE, MEDIUM AND LOW CAPACITY CONVEYORS
- HIGH POWER, LOW CONSUMPTION
- NO SHOCK LOADS


LIGHT DUTY SWING ARM TYPE SAMPLER
● CONSTANT VELOCITY
● DOUBLE CUT FEATURE
● GRAVITY DISCHARGE
● LOW MAINTENANCE
● SELF CLEANING SAMPLE RECEPTACLE
● RACK AND PINION DRIVE

Annex 5

BIRLA JUTE AND INDUSTRIES LTD
SATNA CEMENT WORKS
(Madhya Pradesh)

Located immediately adjacent to the town of Satna, this works comprises a dry-process kiln, two wet kilns and a semi-wet kiln; the latter three kilns are to be replaced by a dry-process plant to be commissioned in 1991. The dry-process plant is an FLS two string suspension pre-heater, one string having a pre-calciner. Under normal running conditions the feed from both sets of cyclones is fed to the pre-calciner, however if this is not operational one cyclone string is used as a simple SP. The capacity of the plant is 1.38 million tonnes of clinker per annum, of which 0.8 million tonnes are produced by the dry process. The new pre-calciner plant will have an output of 0.87 million tonnes per annum.

The raw materials are obtained from a quarry situated about 5 km from the works and connected to it by 4.2 km long aerial ropeway. The pre-blending system consists of two linear blending beds, each of 20,000 tonne capacity, one of which is being constructed whilst the other is being discharged, there being only a single reclaimer. The wet plant is fed un-blended stone direct from the quarry although stone from the blending bed is sometimes used. Current practice on the blending beds is to utilise a small section (about 6000 tonnes) at the end of one blending bed for high grade stone, and at the end of the other for low grade stone, thereby reducing the total capacity of the blended stone.

The homogenisation of the raw meal for the dry kiln is accomplished by means of an FLS designed continuous controlled flow system. The wet-process has eight blending tanks available for preparation of the kiln-feed slurry.

Problems reported by the works :

1. Quarry : It was indicated that due to the bad condition of much of the mobile and fixed plant, it was difficult to supply the works with the quantity and quality of raw material which they required.

2. Works : It was reported that the quality and quantity of stone received at the works was often not adequate to prepare the correct kiln feed composition. The impression gained was that this situation was worse during the monsoon period.

Other problems discussed were:

a) The inability to blend the short sections of the blending beds containing the high-grade and low-grade stone due to the danger of overloading the motor due to frequent reversals.

b) Concern over the sampling of the stone received from the quarry.

c) Highly variable quality of coal, together with shortages of fuel from time to time.

d) Build-ups in the dry process cyclones and coating in the ID-fan.

Problems in the quarry :

The resource area is relatively large, the lease area covering some 10 km^2. Two areas totalling 5.5 km^2 have been prospected and declared reserves, containing some 95.3 million tonnes. One area has been divided into two sections by the erection of various buildings; one half contains the present quarry which is becoming exhausted. A study of the prospecting data for these areas, together with discussions with the quarry personnel, have indicated that in no way can these deposits be considered as being 'proved reserves'. The standard of the original exploration drilling was completely inadequate in terms of a cement works investigation, the analyses were only undertaken for calcium and magnesium carbonates. The division of the deposit into blocks of different grades of stone has been based on total thickness whereas the quarry is worked in two benches. It can only be assumed that the works has continued to function adequately because, firstly the strata is more uniform than believed and secondly the works' geologist has an intimate personal knowledge of the deposit gained over many years association with it.

Visual inspection of the quarry indicates that the strata in the area consists of thinly bedded argillaceous and silty limestones dipping very gently to the south. Within these beds are located relatively large lensoid bodies of purer, stromatolitic limestone. These higher grade areas do not extend the full depth of the deposit, however it appears, from the very limited accurate data available, that where they do occur, an overall analysis of the sequence, which will include both the pure and impure limestone is approximately kiln feed. In areas where no lenses of purer limestone occur the overall analysis is well below kiln feed.

If the deposit is to provide a continuing supply of raw materials to the works, in a form which is capable of being blended to a uniform kiln feed, the exact location of the high-grade limestone areas must be determined, their accurate total analyses ascertained together with details of the chemical variation within them. Similar information must be obtained for the low-grade stone. On the basis of this data, it will be possible to identify an area which has an overall average composition similar to that required as kiln feed (prior to the addition of any additives such as iron ore). The deposit would be worked by quarrying low-grade and high-grade stone simultaneously. The concept of working two grades of stone which can then be blended to give the required mix is, quite correctly, followed at present. However, the exploration data is quite inadequate to identify such areas accurately enough to always ensure a correct final, blended, composition. This problem is compounded by the fact that, in the present quarry at least, the high-grade stone overlies the low-grade stone, the latter not being worked in the monsoon due to flooding of the lower bench.

A further restriction on the choice of material from the quarry during the monsoon period is the fact that, in the top bench, fissures containing clay are present in many areas. Normally this clay is removed by screens prior to the secondary crushers, however, in the wet season these blind, allowing wet clay through the system to cause blockages further along the raw materials stream. As a result only clean stone can be worked during the rains thereby limiting the amount of blending which can take place.

The quarry mobile plant would appear to be adequate to handle the required quantity of material as well as remove overburden. On the basis of the works annual capacity of 1.38 million tonnes of clinker, the annual requirement of approximately 2.2 million tonnes of raw materials should be won with very little difficulty with the three shot-hole drills available. Despite only having (reported) 4.2 tonne buckets the four loading shovels should be able to load the quantity of stone assuming a three shift system, each of five hours, operating seven days per week. In fact three shovels could perform the task on this shift basis assuming an availability of 85%. This would allow one shovel to remove overburden although it is assumed that the rope-excavators and three bulldozers could satisfactorily perform this and other quarrying tasks. The only disadvantage of the existing excavators in the quarry is that all are tracked plant and therefore can take an appreciable time to move, when necessary, from one part of the quarry to another.

The fleet of thirteen dump trucks should also be adequate to move the stone to the crusher, even when taking into account two will be utilised for overburden removal and three are considered obsolete. Assuming an average cycle time of 15 minutes per dump truck, an availability of 60% would be required to perform this task using the present shift system. The future quarry area is about 3 km from the crusher and may require a 30 minute cycle. On the basis of an annual requirement of 2.67 million tonne of stone and a vehicle availability of 85%, ten dump trucks would be required to transport the limestone. It is considered surprising that the new crusher should be constructed at the old quarry rather than the future one, since a 6 km round trip will be required for each dumper load.

In order to produce 2.2 million tonnes of stone per annum, the jaw crusher, which was reported to have a capacity of 500 tph, would require an availability of about 85%. The crusher has therefore only just adequate capacity for present requirements, a fact that has been appreciated and a new double roll impact crusher is being is being installed. However, the fact that the jaw crusher only has an availability of about 70%, being down for servicing for four hours each day, must contribute to the problems of lack of stone; during this time the 250 tph stand-by gyratory crusher is utilised.

The availability of remaining plant in the quarry is poor being reported to be as follows:

shovels	75%
rope excavators	50%
dump trucks	50%-60%
bulldozers	50%
drills	67%

The primary crusher produce a -200 mm product which then passes over 12 mm screens before the two secondary hammer mills. These screens are used to remove clay cavity material which is then dumped; it can be put back into the system in the dry season to generate low grade material if required. Due to potential blinding of the screens in the monsoon season, only limestone with minimal clay can be put through the system at this time. Even so build-up of material in the secondary crushers can apparently occur and grate bars are reportedly removed to stop this. This allows oversize material to pass from the secondary crushers causing milling problems later in the raw material preparation. The design discharge from the secondary crushers is -25 mm.

The crushed stone is dropped directly onto four vibratory feeders at ground level which feed the belt to the ropeway loading point. Should a stock of stone be built up on these feeders, the grade of material being sent to the works cannot be changed until this stock is bulldozed off.

Problems in the plant :

Stone from the aerial ropeway discharge is sampled at a belt transfer point en route to the blending bed/wet kiln plant. This sample, taken from three positions by hand, is not adequate. Although the repeated sampling to prepare a periodic bulk sample produces approximately sufficient material, this material cannot be representative. The fact that this form of sampling appears, superficially, to provide adequate control the construction of the blending bed, once again supports the suggestion that the raw materials are fairly uniform.

The blending bed itself is limited by the stacker to a chevron blending form. The short length of the stockpiles used for high and low grade material, at the ends of the main beds, result in them being stacked from a stationary position due to the danger of damage to the motors by frequent reversals.

Reclamation of the stone from the stockpiles appeared to be satisfactory although build-ups were reported at belt transfer points in wet weather. This problem, caused probably by water absorption into the uncovered stockpiles is probably compounded by the inclined walls of the hoppers at the transfer points.

The raw materials, blended to approximately kiln feed on the blending beds, can be finally adjusted prior to the mill using the weigh-feeders beneath the mill-feed silos. The main silo, of 600 tonne capacity, contains the blended stone, a smaller 200 tonne silo can be filled with either low-grade or high-grade stone, and the third silo, also of 200 tonne capacity, with iron ore. The main problem which is likely to occur at this point is that, due to poor raw material control, the grade of the blended stone will vary so that there will be a change in requirement from, for example, high-grade to low-grade additive when the 200 tonne silo is almost full of high-grade material. This switch in requirement could occur when a change was made from one blending bed to the other.

Problems of the feed size to the raw-mill were noted above.

The controlled flow blending system is reported to work well unless the silo is less than one third full. This is to be expected as the system is designed to be used with the silo as full as possible.

The conditions in the dry kiln were dusty when the plant was visited, in contrast to the dry kilns which had little dust. Problems of blockages in the cyclones and build-up in the ID-fans were reported. Analyses of the ID-fan build-up indicated sulphur contents of up to 11% (as SO_3). The circulating sulphur load in the kiln gases is not measured.

Since the ash content of the coal is high, this must be considered as a raw material. The coal used on the works has an ash content of between 28% and 34%. The calorific values varies accordingly. Assuming that 80% of the ash is absorbed, this could result in the ash constituting about 4.5% of the raw mix. Thus if a uniform and good quality clinker is to be produced this cannot be achieved by uniformity in the kiln-feed alone, the coal used in the plant must have a uniform ash content and analysis. Blending of the coal is not undertaken, although blending facilities exist, one reason given was that stocks are often so low that the material has to be used as it arrives. One further aspect to the uniformity of the coal is that the pre-calciner will have been designed to operate efficiently with a certain grade of fuel. Variations from this norm will effect the efficiency of the whole system. Not only does the ash content of the coal vary widely, but so does the content of impurities. A visit to the coal storage area for the wet kilns indicated that some consignments of fuel contained considerable quantities of iron pyrites; up to 50% of some pieces of coal were pyrite. This feature could well be associated with the build-ups which occur in the cyclones and ID-fans.

Recommendations

1) The raw material resource be re-surveyed, using methods which will achieve the required minimum of 96% core recovery, on a 200 metre grid basis. All samples to be analysed for silica, alumina, iron, calcium, and magnesium; selected grouped samples to be analysed for minor elements such as sulphur, alkalis, manganese, and phosphate.
2) The survey data to be assessed in order to give an overall development plan for the total life of the deposit and detailed one and five year plans.
3) The quarry floor should be inclined gently to the south, following the regional dip, in order to allow natural drainage away from the working faces in the monsoon period. When this is not possible a drainage ditch should be made leading to a sump equipped with a pump. This de-watering of the quarry will allow working of the lower bench during the monsoon thereby leading to a constant ex-quarry stone chemistry throughout the year.
4) A thorough and detailed assessment of the condition of the mobile plant and the maintenance procedures should be carried out in order that the availability of the equipment can be brought up to an acceptable level.
5) Tests should be carried out using 25 mm screens before the secondary crushers during the wet season in order to determine whether or not clayey stone can be used without overloading the waste belt or losing an unacceptable quantity of limestone to waste.
6) Installation of a proven stone sampling device (such as the swinging arm type sampler illustrated in Annex 4) at the transfer point between the new crusher (under construction) and the stockpiling area. Samples to be taken at frequent intervals (to be determined by experiment) and grouped into hourly samples. These should be analysed immediately, preferably in the quarry.
7) Re-design of the stockpiling area in the quarry so that the new crusher can supply stone to separate high-grade and low-grade blended piles. Extraction and transport to the rope-way feed hopper could be by wheeled loader. Ideally the planned shuttle conveyer could be

extended to allow four piles to be prepared. This would allow high-grade and low-grade stockpiles to be built simultaneously with extraction from two completed stockpiles. The two high-grade (or low-grade) stockpiles need not be physically separate (although low-grade and high-grade must be) and could take the form of one long stockpile which was being built at one end and whilst extraction was taking place at the other.

8) Installation of a proven stone sampling device (such as the swinging arm type of sampler) at the transfer point between the ropeway discharge and the blending bed. Complete analysis to be made on the hourly (composite) samples from this point to enable accurate control of the blending bed composition.

9) The short sections of blending bed used for high-grade and low-grade material to be stacked correctly by using the slow stacker speed rather then the higher speed used on the main beds. This will reduce the danger of damaging the motor.

10) The blending facilities in the coal store in the form of the travelling shuttle conveyer should be used correctly. The reported problem of the discharge trolley coming of the rails would appear to be a relatively simple engineering problem and should be solved. It may also be possible to remove the dividing wall between the coal and clinker stores in order to provide more space in the coal store to allow two beds to be constructed (these need not be separately by a physical space) so that one can be reclaimed whilst the other is being built.

11) The kiln gases should be monitored for sulphur content.

SATNA CEMENT WORKS

Information collected

Raw Materials

The main components of raw material are :

1. Limestone : Sedimentary, bedded, gently dipping

    Two types of limestone in the quarry -

    High Grade : Upper (first) bench

    Low Grade : Lower (second) bench

98% - 99% of the raw material is limestone. Annual requirement is 2 million tonne.

2. Iron ore : About 1- 2% is added to the raw meal. Requirement is 20,000 tpa and is presently being purchased from Sheohar mines.

3. Indian coal is being used as fuel at the rate of 20-21% coal on clinker, the annual requirement is 0.40-0.45 million tonne.

Raw Materials Analyses

Limestone : There are two types of limestone in the quarry, and these are being blended to get an average quality of limestone as follows :

CaO %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %
43.85	11.8	2.4	1.64	2.35

Iron ore : Average chemical analysis of iron ore, as currently being used is as follows :

SiO_2 %	Al_2O_3 %	Fe_2O_3 %
6.3	13.77	74.4

Coal Quality

There is considerable variation in the quality of coal due to ash and sulphur content. Average specifications are as follows :

Ash content 30-31% (sometimes 35 to 42%)

Moisture content 4%

Volatile matter 21-25%

Ash analysis (average) :

CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO
%	%	%	%	%
1.87	60.46	24.08	6.12	1.57

Transportation details

There are two main systems, dump trucks and an aerial ropeway.

Mobile plant

Dump trucks (capacity 30 t Tarex) - 13 (8 in use, 5 under repair)

Bulldozers - 3 (2 in use, 1 under repair)

Drills - 2 Drill Master (6" diam.), 1 Halco (4" diam.)

Aerial Ropeway

Length of rope: 4.2 km.

No. of buckets: 182

Spacing of buckets: 49 m

No. of buckets/hr: 301

Capacity of ropeway: 650tph

Pay load per bucket: 2.16 t

Speed of buckets: 14.7 km/h

Blending data - Capacities of beds and silos

Blending of high-grade and low-grade limestone is carried out by stacker reclaimers. Total capacity of blending beds is 40,000 t but only 60% (24000 t) is used for blending. Two parallel beds are used, one being constructed and used as storage and the other being reclaimed. The remaining 40% of space is used to store high-grade and low-grade limestone for mix adjustment. The stacker reclaimer has two speeds, 24 and 15 metres per minute.

Continuous Fluidization Silo. This has a capacity of 16,000 t. The automatic fluidization system operates with minimum of 30% storage (i.e. 4800 t) and the system is equipped with seven auto samplers and on-line X-ray analysis.

Analysis of kiln feed

The average analysis of kiln feed is as follows:

CaO %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	LSF	SR	AR
42.28	12.26	2.71	2.29	1.71	1.08	2.45	1.18

Kiln data

There are four kilns.

Three wet process kilns : a) Skoda 500 tpd
b) Skoda 500 tpd
c) Krupp 750 tpd (semi-wet)

These are being replaced by a single dry process kiln.

One dry process kiln : FLS - 2200 tpd kiln (L 64m, D 4.35 m)

Output data

Dry-process 2200 tpd, plus up to 1800 tpd from the wet kilns.

Clinker analysis

The average analysis of clinker is as follows:

CaO %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	LSF	SR	AR
64.10	21.87	4.41	3.90	2.61	0.93	2.63	1.13

Phase composition of clinker

C_3S %	C_2S %	C_3A %	C_4AF %	Free lime %
52.32	28.43	5.20	11.85	1.75

Type of cement and analysis

Normally the plant produces OPC with the average composition :

CaO %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	Free lime %
61.91	22.57	4.34	3.72	2.61	1.84

Sagmania Limestone Mines

The area sanctioned under the mining lease in the Tehsil Raghurajnagar District, Satna, covers an area of 10 km^2 (equivalent to 2470 acres). It lies between 24° 35' 54" latitude and 80° 53' 20" longitude. The cement factory is at a distance of 5 km in a north-easterly direction. The lease is for a period of 20 years, expiring in 1995.

The deposit is of sedimentary origin and belongs to the Bhandar series of Upper Vindhyan System and is overlain by Sirbu shales. The surface is covered by black cotton soil which varies in thickness from a few centimetres to 8 metres. Outcrops of limestone are seen at a number of places and the upper part of the sequence can be seen to be high in magnesia. It is unusable for cement making and varies in thickness from 1 to 5 meters; it is responsible for preservation of large tracts of very high grade limestone below it which have been protected from sub-aerial erosion. The dip is shallow.

In order to determine the quality and quantity of the limestone detailed prospecting operations were undertaken in June 1978. A total of 198 holes were drilled over an area of 5.5 km^2. This investigation finished in 1981 with a total of 3414 meters of drilling. The data collected as a result of the above work is detailed described below; the information having been updated to 31.10.85.

1) Proved (measured) limestone reserves = 50.73 million tonne
2) Indicated limestone reserves = 44.57 million tonne
3) Total reserves estimated, i.e. 1) + 2) = 95.30 million tonne
4) Quality of proved limestone, av. $CaCO_3$ content = 79.43%

5) Overburden ratio 1:6

5a) Overburden in proven area - 4.64 million m^3

6) Long term mining plan -

Current plans indicate that production from the present quarry can continue for at least ten years and the rest of the deposit is likely to last for a further 32 years at the present rate of planned production, i.e. 2.2 million tonne of limestone per annum.

Prospecting Report extracts

Three series of holes i.e. C,A, and CD have been drilled in C, A and D quarries respectively. C and D quarries have been merged to form one single quarry with a very large working face. C quarry has a total of 90 boreholes spread over 15 different blocks with a total area of 1.29 km^2. The drilling was planned on a 100 m grid, however this could not be strictly adhered to due to obstacles, proximity to quarry faces and general experience gained from working the mine. General study of the data obtained has indicated that the limestone in the first 10-11 meters is of better quality than the deeper material. Below that depth there are patches of low grade shaly limestone intermixed with good quality material.

Total area prospected around 'A' quarry = 2.68 km^2

Total area prospected around 'C' quarry = 1.29 km^2

The entire deposit has been divided into 20 blocks, computation of proved reserves has been done on the basis of average depth in each block.

Anticipated deviation on grade calculation less than 1% CaO

Permissible errors on reserve calculation less than 10%

Earlier when the prospecting was started these errors were allowed for. CaO as determined by analysis is generally more than what arrived at by calculation from the total analysis.

Current Planning

Current planning of 'C' quarry can continue for ten years at the present rate of production. Face layout, benches etc have already been developed. Bench height may have to be modified according to the depth of the limestone as indicated in various blocks. Position of auxillary sump may need to be changed from time to time to remain nearer to working benches so that working can be kept dry.

Reserves currently under permanent structures have not been estimated as it is not minable at present. However if these permanent structures are demolished at a later date underlying limestone can be mined. This is possible by installing a portable crusher and moving buildings when they become fully depreciated.

Reserves underlying areas blocked by villages and proximity of inhabitation need estimation.

SATNA CEMENT WORKS

Personnel who participated in discussions :

Mr J N Prasad	Sr. Vice President
Mr B Dutta	General Manager
Mr C V Singh	Sr. Mines Manager
Mr P K Mukerjee	Sr. Geologist
Mr D Roy	Geologist
Mr N Ghosh	Manager Central Chemical Labs.
Dr R Chatterjee	Sr. Chemist
Mr Joshi	Chief Burner (Wet Process Kilns)
Mr Parihar	Engineer (Ropeway)

Names of NCB counterparts :

Mr S K Gotecha	Geologist
Dr V K Mathur	Chemist

Annex 6

MADRAS CEMENTS LTD.
RAMASAMYRAJA NAGAR CEMENT WORKS
(Tamil Nadu)

The Ramasamyraja Nagar cement plant is a single kiln, dry-process works. One wet kiln remains on the plant but is not utilised. The plant was designed by Holderbank and utilises F L Smidth equipment, the kiln being the first 1,200 tonne per day unit to be installed in India. When first commissioned it is reported that the kiln could not continuously attain its design output, only between 800 and 1000 tpd being normally achieved. The full reasons for this were not ascertained, however it is clear that the quarrying techniques in use when the initial design samples were taken were altered by the time the dry-process came on stream. The principal difference in quarry working was a change from manual to automated materials production and preparation, resulting is less efficient removal of impurities in the raw material. In addition the original mix included a sand which reportedly contained alkalis which caused blockages in number four cyclone. Modifications to both the quarry, in the form of hand-picking belts, and the kiln by the addition of a works designed secondary firing system, later modified to a simple pre-calciner, has enabled the output to be increased to a reported 1,350 tpd. Unfortunately at the time of the visit the plant was not operating as major repairs were in progress. These included the replacement of a kiln section which had broken in half. The works' staff suggested that this kiln failure was brought about due to the large distance between the kiln rollers, coupled with the frequent ring development in this part of the kiln. The plant produces Portland Pozzolan Cement.

General : The importance of a detailed knowledge of the raw materials coupled with detailed quarry development planning is clearly appreciated, not only by the quarry personnel but also by the works in general. The high caliber of the quarry personnel is demonstrated in the well organised quarries, located in what is a relatively complex deposit. It should be noted however that as well as obtaining stone from three quarries a further five materials are purchased. This large number of materials is considered too complex.

The raw materials : A narrow belt of limestone outcrops in the form of an arc passing from the western side of the works, round the north and down the eastern side. Although potentially continuous, this belt has only been proved at a number of locations. West of the works the known limestone was used for the original wet-process and is now exhausted. East of the plant there are three quarries. The nearest at Kalluppatti is potentially complex, the limestone being inter-folded with alleged charnockite. However on-going exploration is delineating the workable limestone which is extracted by drilling and blasting; size reduction is by hand. Both low-grade and high-grade stone are present at Kalluppatti, the total reserve has currently calculated at 0.8 million tonnes. At a distance of 22 km from the works the Pandalgudi quarry is the location of the main quarry complex including the crushing plant. This 5 km long belt of limestone is partially worked out, an estimated 3.5 million tonne of high-grade stone remaining. A further 6.5 million tonne of stone, both high-grade and low-grade occurs approximately 17 km further along the strike from Pandalgudi at Melvenkateswarapuram. However the mineral lease only covers a 2 km stretch of this 5 km long resource; the remaining length is currently the subject of a lease application. Low-grade stone is obtained from the source but the size reduction is by hand. The quality of the stone varies, not only along the strike but also across the width, the uppermost part of the limestone (the hanging-wall) being more contaminated with blocks of black charnockite than the lower part of the bed. Although a reasonable reserve exists it is suggested that exploration for limestone at predictable locations nearer the works should continue; the NCB can be of assistance in this matter.

Exploration : A diamond core drill not only undertakes exploration drilling in raw material deposits but is also used to delineate exactly the bodies of limestone which occur within existing quarry areas but which, due to complex folding, may not be in the general trend of the strata or which may be inter-folded with unusable material. Although this drilling on a 100 m grid is of a reasonably high standard it is not adequate to obtain all the information which can be of importance in a cement raw material. This is due to the use of small diameter core, relatively old fashioned core recovery tools and a general lack of appreciation that better recovery is possible.

Planning : Every half metre of core has been analysed for $CaCO_3$ and the results utilised to manually develop a reserve of 100 metre square blocks, each of bench height 10 metres. The overall silica, alumina, iron and magnesia has then been obtained for each block using the borehole core. From the data obtained geological and quarry maps and sections have been prepared.

It has been suggested that computerised planning could be used in the quarry since computer software designed for such purposes is available both commercially, for example the Computerised Evaluation System (CES) of F L Smidth, and through the NCB. From the evidence available it would not appear that such techniques could improve upon the method currently utilised at the works. Moreover the physical shape of the deposits, narrow steeply inclined limestone, results in many problems when the mathematical methods used in such programs are applied. All the sophisticated mineral assessment software assumes some form of relationship between the samples which are supplied to the program; in the case of quarry planning systems this tends to be borehole data. Such data must always be accurate and complete, in other words 100% core recovery is required. This is not available for these deposits. Secondly the position of a sample is important. The estimated analysis of a block of limestone within a deposit is calculated on the basis of all the samples both within it and also surrounding it. For blocks of stone in the centre of a deposit this can give reasonable results, for those at the edge all the data lies to one side and the result is a grade estimate considerably less accurate. The narrowness of all the limestone deposits, as low as 20 m in places, results in all the data suffering from this 'edge' effect if pure mathematical methods are used. When manual methods are employed the experience and information obtained in working the deposit over many years can be utilised in interpretation of the drilling data, a feature not normally available in computer software.

The fact that complex computer assisted assessment methods are not considered appropriate in this case does not preclude the use of computers as an aid to efficient operation of the quarries. Rapid calculation of volumes, planning the correct use of dump trucks for face blending and similar calculations can be speeded up with the aid of a computer, especially a micro-computer. Such modules exist in quarry packages available from many sources including the plant manufacturers. However it would not seem to be cost effective to purchase such a complex system in order to utilize only one or two small modules in it. The routine quarry records of plant use and analyses are already in the process of being computerised in the works' EDP department. The nature of the reports to be produced appear to be useful and very similar to those produced by commercial software. It is suggested therefore that the quarry personnel should maintain the close contact which has clearly been made with the EDP department and jointly produce relevant computerised aids to efficient quarry working as and when required.

<u>Extraction of the limestone :</u> The present system of drilling and blasting would appear to be satisfactory. The steeply dipping nature of the strata is such that the stripping ratio will increase with depth, the quarry is widened to maintain stability as the depth increases. A maximum overburden ratio of 4:1 is considered acceptable. Widening of the quarry to allow deeper quarrying as the depth increases results in the instantaneous stripping ratio matching the overall stripping ratio of 4:1. Where the width of the limestone is small blasting has to be undertaken across the

strike resulting in poor fragmentation at times. Wherever possible a narrow slot is driven along the foot-wall to enable blasting to be undertaken parallel to the strike, resulting in better fragmentation. It should be noted that the direction of quarrying will result in different patterns of chemical variation within the blasted rock since the limestone is more contaminated near the hanging wall (top) than the foot-wall (base). A face at right angles to the strike will have potentially better stone when it is near the foot-wall than when it is near the hanging-wall. The blast-hole dust should be used to monitor the variation prior to blasting and this variation taken into account when loading. The loading and transportation of the stone would appear to be satisfactory, although if a shovel continues to load from a single point on a blast for any period of time, a variation in grade could be experienced as the removal of stone progresses.

Maintenance of the mobile plant appears to be satisfactory, averaging between 75% and 80% availability; there is a reported spares problem at times. The monsoonal rains do not affect production, the quarry floors being sloped and water pumped from sumps.

Raw materials handling at the quarry : Although three quarries produce stone there is only one crusher, at Pandalgudi. Stone preparation at Melvenkateswarapuram, the main source of low-grade stone, and Kalluppatti is by hand. A mobile crusher for Kalluppatti is planned. When hand preparation is practiced the removal of black, siliceous charnockite inclusions is good, however at Pandalgudi the direct feeding of the blasted stone to the crushers results in the necessity to utilise hand-picking belts prior to the secondary crusher. Although relatively efficient, it is reported that about 60% of the black stone is removed increasing the carbonate content from 73-76% to 80-82%, there is some evidence that an improvement in the removal of the siliceous material could further benefit the works. It is possible that the limestone upon which the dry process plant was designed contained less black charnockite contamination than the present feed. There is no doubt that the limestone sent to the works has a high silica ratio although the alumina ratio and

LSF are approaching that required for kiln feed. The charnockite has a higher silica content than the overall limestone received at the works and therefore removal of more of this stone would reduce the overall silica content without necessarily affecting the alumina ratio; the LSF would increase which is desirable. Visual inspection of the belt leaving the hand picking station suggests that a large proportion of the black stone in the feed is between 25 mm and 75 mm in size at this stage. If this observation can be shown to be correct it may be possible to separate this fraction, either by further hand picking or by treatment with an optical sorter.

The primary crusher at Pandalgudi is a Humbolt double toggle jaw crusher rated at 300 tph. No problems are reported. Material under 100 mm bypasses the crusher by means of a grizzly. This fine material is screened (15-25 mm in the dry season, 50 mm in the wet season) and the undersize rejected. However sampling of this fine material is undertaken and if the carbonate is in excess of 70% it is stacked separately and may be used to generate low-grade stone. The reject rate is about 5%.

Storage and despatch in the quarry : From the crushing plant the stone is carried by a conveyor to one of the two 400 tonne hoppers, one for high-grade the other for low-grade stone; contractors' lorries are then filled from these hoppers for transport to the works. The system is considered limited and a stockpiling system consisting of two piles constructed by a luffing conveyor would be preferred. The two blended stockpiles which would result, one of high-grade the other low-grade stone, should be worked from their ends using a wheeled loader as a reclaimer. Such a method would minimise the segregation which may be occurring in the present silos and which may therefore be introducing a chemical variation in the stone despatched to the works. A greater capacity of reserve material could also be stored than at present. A boom with a swing radius of 10 metres could easily accommodate two piles of 1000 tonne capacity each; the larger the piles the greater the blending effect, resulting in more flexibility in the choice of material extracted from the limited choice of faces available in the quarry.

The composition of the stone in the present silo is determined by continuous sampling of the feed belt, by hand, for a period of 45 minutes, with a break of 15 minutes whilst the sample is taken to the laboratory. This method is completely unsatisfactory. The only way in which to sample coarse stone is to remove a complete section of belt at frequent intervals and then combine the samples over a period of about one hour. A swinging arm type of sampler (Annex 4) will take such samples correctly.

Receipt and storage of the raw materials at the works : The stone is tipped from the lorries into a hopper which feeds the belt to the top of the stone store, a travelling discharge point at the top of the stone store is used in stationary mode to build a cone of material over one of twelve vibratory feeders set in the floor of the store. This system is unsatisfactory since segregation will occur in the cone of material, the physical segregation almost certainly having a matching chemical segregation. The travelling discharge point should be used as a stacker, continuously travelling up and down the store. Discharge should be from all the vibratory feeders simultaneously. A funnel-flow blending system will thereby be developed, the outer parts of the stockpile remaining static and acting as walls whilst the inner parts cascade. It is essential that the store be kept full if such a method is to work. The target grade of the stone should be a little above kiln feed as at present. One end of the store, perhaps equivalent to three or four feeders, could be used in the same manner for low-grade stone. Sampling of the stone prior to the stone store should be undertaken to allow feed forward control to the mill rather than relying on feed back control from the mill product as at present.

Other raw materials : In the storage area at the works a range of raw materials is available for kiln feed adjustment. Kunker (two types) for use as a low grade material, high-grade limestone from Ariyalur for use as a sweetener, crystalline limestone from Rajapalayam for use when monsoonal rains cause handling problems with other stone, bauxite and iron ore. The most important of these is the kunker (a calcrete) which is used as the low-grade stone utilized for bringing the blended stone from the works quarries down to kiln feed. In order to handle the material, which is clayey, it is mixed with an equal quantity of crystalline limestone from the works quarry (in the monsoon two parts of crystalline limestone are used with one part of kunker). The calcrete is worked by a contractor from variable deposits in a haphazard manner. Its analysis is determined by random sampling from the lorries which transport it to the works. It is stored as a series of discrete piles and extracted in no regular manner. Calcrete is one of the most variable and difficult raw materials for cement manufacture and the present system of utilization is completely inadequate. Every effort should be made to replace it with low-grade stone from the works' own crystalline deposits. The analyses supplied by the works of the Kalluppatti limestone are very similar to the kunker analysis also provided by the works personnel. Theoretical mixes can be produced using Pandalgudi and Kalluppatti limestone together with a little bauxite and iron ore for moduli adjustment; there is no requirement for sweetener or kunker. If it is found that the calcrete is necessary the works should locate, prove and work its own kunker deposit. Major improvements can be made in the handling of kunker in the present system by tipping the lorry loads in a regular manner and building up a 'layered' pile to be extracted by wheeled loader. Every care should be taken in handling kunker as it segregates into coarse and fine fractions very easily.

The Rajapalayam limestone is not suitable for cement manufacture and its use should be discontinued.

The Ariyalur limestone, if required, should be stored, whenever possible, in a manner similar to kunker.

Further raw material development : The low dip in the Melvenkataswarapuram limestone may allow the use of underground extraction once the present quarry is exhausted.

The works : The clinker quality appears, on the basis of the data supplied, to be variable. Rings in the kiln and cyclone build-ups also occur. However the reason for these is difficult to analyse since not only is the kiln-feed variable, an LSF range of between 1.01 and 1.10 being noted on the basis of four analyses, the coal ash is also variable, up to 8% difference in ash content on two consecutive days; the SO_3 content of the coal can also vary between at least 1.25% and 2.91%. Moreover the raw meal can have up to seven components, the proportions of which vary daily. Thus until better control and standardization of the raw materials can be achieved it is likely that variable kiln conditions will continue leading to build-ups of one type or another.

The number of different types of coal utilised is as great as the other raw materials. At the time of the visit five heaps of coal were identified, these being west Indian coal, east Indian coal, Australian coal, coal fines and lignite. Apart from the lignite, which is added at the coal mill, the other types of fuel were mixed by loader as they were retrieved and dumped into the main coal store. Extraction from the store is by overhead clam-shell bucket. This method is not adequate to ensure a uniform material. The requirement for blending being made apparent by the quantities of coarse white sandstone which contaminated some of the Indian coal. The equipment for transferring the coal to the coal store from the stockyard must be utilized in a much more methodical manner in order to blend the coal.

Recommendations

1. A minimum core recovery of 96% is essential in exploration drilling for cement raw materials since it is frequently in the fine, soft, material which is lost that the harmful impurities occur. The core barrel used for exploration should be changed to a thin walled type of a larger diameter than at present. A minimum diameter of about 55 mm (N size) is required. Training of the drillers should also be undertaken to ensure that they have more positive control of the drilling, especially in soft or broken ground; such training should also include an explanation of why it is so important to obtain perfect core recovery.

2. The facilities and expertise available at the NCB for the interpretation of aerial photographs and satellite imagery be used to locate potential target areas for exploration nearer to the works than the present quarries.

3. Due to variation across the deposit due to changes in the concentration of inclusions of black charnockite, every effort should be made to sample the blast hole dust chippings as accurately as possible in order that analyses can be made to identify the variation in the block prior to blasting; patches of white silica rock can also be identified at this stage. The sample division method used at present when handling blast-hole chippings is coning and quartering. This is not accurate and a correctly sized riffle, or preferably a rotary cone sampler, should be used.

4. On the basis of the chemical analysis of the blast-hole dust, the excavator used to load the dump trucks should be moved frequently to ensure uniformity of the stone sent to the crusher.

5. The uppermost five metres of the limestone in the Melvenkateswarapuram quarry are very broken and contaminated with overburden. Consideration should be given to removing this material as a separate bench thereby

enabling the more solid, cleaner, stone below to be worked is not contaminated. Such a procedure would minimise the danger of loose stone from the top of the quarry sliding along the joint planes down the face; a more uniform product may also result.

6. In order to maintain a reliable supply of low-grade stone from Melvenkateswarapuram, early installation of the mobile crusher would appear to be essential. As the use of such equipment would remove the necessity for hand preparation, it will be essential to install a hand picking belt if an excess of unwanted black siliceous material is not to occur.

7. The stone leaving the existing hand-picking station should be sampled prior to the secondary crusher in order that tests can be carried out to determine the size distribution of the remaining black stone. In order to obtain an accurate result about ten oil-drums full of sample would be required of stone of this size. The samples should then be screened on various mesh sizes in order to determine the percentage of each size fraction; these would then be sorted into black and white material. The result of such an experiment would enable the distribution of black material to be ascertained and therefore the possibility of removing an appreciable amount of it by hand sorting a specific screened fraction. A similar experiment could be performed on the feed to the fine sorting belt to determine whether it is feasible to split off a specific fraction prior to the existing hand-sorting procedure. An alternative to hand-sorting would be an optical sorter. This may allow a greater throughput since the conveyed material could travel at a higher speed than for hand-sorting.

8. Serious consideration should be given to the storage of crushed stone in the quarry in the form of two stockpiles, high-grade and low-grade, formed by a single luffing conveyor used as a simple stacker. Reclamation from the piles, the capacity of which should be as high as possible to enable their blending effect to allow more flexible

quarry bench working, would be from the ends using a wheeled loader as a reclaimer/loader.

9. The hand sampling of ex-crusher feed to the storage hoppers in the quarry should be replaced by an automatic sampler. A swinging arm sampler (Annex 4) is recommended. Samples should be taken at intervals over each and every hour. The frequency of sampling should be determined by experiment but would probably be of the order of at least twelve samples per hour. Sample reduction should be by laboratory-size hammer mill and rotary sample splitter, although appropriately sized riffles could be used if necessary. Coning and quartering should not be used.

10. The works' stone-store should be used as a blending-bed. Continuous traversing of the trolley carrying the discharge point in the top of the store would produce a layered stock-pile of material, the target grade of which should be just above kiln feed as at present. Simultaneous discharge from all the vibratory feeders will cause a cascade type of blending within the mass. Although much of the material, especially the outside and ends will remain as static reserve, the moving material will blend to a greater or lesser extent. To operate satisfactorily the store must be kept full. One end of the store, equivalent to about 3 or 4 discharge holes could be used in a similar manner for low-grade stone.

11. An automatic sampler of the swinging arm type should be installed prior to the stone store. This will enable an accurate picture of the grade of stone to be obtained and also allow accurate extraction from the quarry stockpiles to give a precise grade of stone at the works. Details should be as in recommendation 9 above. Analysis of these samples should be for all elements allowing precise forward control of the mill-feed hoppers. A further refinement giving even better control of the mill feed would be to install a further sampler between the stockpile and the mill hoppers.

12a. The use of kunker should be avoided if at all possible and mixes prepared from crystalline limestone only. The analyses provided of Pandalgudi and Kalluppatti limestone indicate that perfectly adequate compositions can be achieved with the aid of bauxite and iron-ore alone. If quantities of suitable crystalline stone cannot be constantly obtained then recommendation 12b refers.

12b. If kunker is considered essential to attain a good mix the works must control its own kunker deposit. An exploration drilling programme on a suggested 500 m grid in those areas where black cotton soil is present is suggested; kunker may occur in other areas but may be limited in thickness. Once a deposit as thick as possible and as close as possible to the works has been located it should be prospected by means of pits on a suggested 200 m grid. Only one sample per pit is required covering the full thickness of the kunker. Full analyses should be carried out. Should no pattern of chemical variation be found from these samples, in other words random variation appears to exist, the sampling pit grid should be closed to 100 metres. If the results of the close sampling still fail to provide adequate information on the chemical variation in the deposit then the NCB should be contacted for assistance using more sophisticated statistical methods of assessment.

13. Kunker should be worked from a long face, the extraction equipment moving continuously up and down the face in order to blend the material. Random digging should be stopped. Overburden must be completely removed even if this means removing the top few centimetres of the kunker deposit.

14. Stockpiling of kunker at the works should be done by making a simple blending bed using the lorries delivering the material. Tipping should be on a regular rectangular basis so that once a reasonable area has been covered the heaps can be flattened and samples taken from the surface. The next loads of stone are tipped on this surface and the process repeated so as to build up a layered pile. Each layer

will have been sampled and the overall analysis of the heap is therefore known. Extraction of stone would be by wheeled loader from the end, the machine extracting from the complete width of the pile. Should compaction of the kunker occur a back-hoe or similar hydraulic attachment may be required to loosen the material prior to removal.

15. The Rajapalayam limestone is unsuitable for cement manufacture and its use should be discontinued. Should a reserve of crystalline block be required on the works, this should obtained from the works own supply.

16. Whenever possible the Ariyalur limestone should be stockpiled in a manner similar to kunker as in recommendation 14.

17. The wheeled loader used to transfer coal to the stockpile from the storage area should be used to build up a regular, rectangular layered heap. Once a mixed rectangular layer has been made this should be flattened, the surface randomly sampled and the next series of loads tipped on top. The process is repeated until the stockpile is of sufficient size. The overhead grab should then extract the coal in a regular manner starting at one end. In this way a more uniform fuel supply of known quality will be available.

18. The number of both the raw materials and fuels is too great. Moreover the quality of each is variable and often not known adequately. Every effort should be made to reduce the number of components and use them in a constant manner.

RAMASAMYRAJA NAGAR CEMENT WORKS

Information collected

Geology : The limestone formation in the area is of Archaean age and occurs as a steeply dipping band with charnockite forming both foot-wall and hanging-wall. This sequence in turn occurs within pink granitic gneiss. Occurrences of crystalline limestone with garnetiferous gneiss and granitoid gneiss have also been reported. The regional arcuate distribution of the limestone from Tulkkapatti in the west to Pandalgudi in the east is presumably due to folding along a north-south axis. The limestone, which is white to greyish in colour, is characterised by the occurrence of numerous inclusions and/or intrusives, all of which tend to be apparently random except for a 7 m wide band in parts of the area. Veins of quartz, pegmatite and calcite are present in places, as are disseminated particles of greenish pyroxene, graphite and mica.

Some of the uncontaminated limestone can be of a very high grade :

	%SiO_2	%Al_2O_3	%Fe_2O_3	%CaO	%MgO	%LUI
White limestone	5.5	1.1	1.0	51.3	1.1	40.2
Grey limestone	1.6	0.6	0.4	54.1	0.4	42.7

However the limestone is normally contaminated to a greater or lesser extent with charnockite, a typical analysis of which is :

%SiO_2	%Al_2O_3	%Fe_2O_3	%CaO	%MgO	%LOI	%Na_2O	%K_2O	%Cl
62.1	12.8	5.8	8.5	2.0	2.9	4.4	0.7	0.01

Typical analyses of the various limestones as received at the works are as follows :

Pandalgudi :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
9.57-17.07	1.87-3.02	1.13-1.76	42.23-47.74	1.35-1.60

Kalluppatti :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
11.91-21.28	2.46-4.11	1.66-2.45	40.23-46.29	1.60-2.56

Melvenkateswarapuram :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
9.78-13.20	2.07-2.13	1.45-2.38	45.20-47.49	1.46-1.79

Ariyalur :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
2.27	1.15	1.92	52.20	0.92

Rajapalayam :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
15.83	1.00	0.84	38.23	6.50

The variation in the composition of the black stone (charnockite) is reported as follows :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
17.35-28.63	3.48-8.77	2.98-4.88	31.38-42.61	nil-1.95

The variation in the composition of the other components is reported as follows:

Kunker :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
12.66-25.85	2.86-4.90	2.25-3.02	34.53-41.62	1.90-2.19

Bauxite :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
9.40-9.85	41.84-44.78	20.71-25.27	-	0.50-0.55

Iron ore :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
2.00-2.80	6.00-6.10	84.00-85.90	0.23-0.60	0.30-0.40

Works quarries :

	Pandalgudi	M V Puram	Kalluppatti
Mining Lease	503.44 h	255.85 h	78.74 h
Reserves	6.0 Mt (measured) 5.0 Mt (inferred)	6.5 Mt (indicated)	1.2 Mt (measured)
Production	850 tpd	400 tpd	150 tpd
Waste	2180 tpd	425 tpd	475 tpd
Mobile Plant :			
Drills	2 x BVB 25	1 x BVB 25	1 x BVB 25
Shovels	2 x Hind Demag 3.3 m^3	1 x Hind Demag 3.3 m^3	

Loaders	1 x HM 7.5 yd^3 1 x HM 1.9 yd^3		1 x HM 7.5 yd^3
Dump Trucks	8 x HM 25 t 2 x HM 35 t	2 x HM 25 t	2 x HM 25 t
Bulldozer	1 x HM 8240		
Exploration drills	2		

<u>Kiln feed :</u>

Typical raw meal components (10.08.87)

Pandalgudi limestone 50.91%
Ariyalur limestone 5.14%
Nodular kunker 19.02%
Lumpy kunker 5.14%
Other limestone 17.99%
Bauxite 1.08%
Iron ore 0.72%

Range of analyses provided by the works as follows :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
12.57-13.00	2.68-2.93	2.54-2.74	43.74-44.75	1.30-1.40

Coal :

Kiln feed coal ash :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
61.76	22.36	6.70	4.30	2.60

Lignite ash :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
24.00	31.20	7.37	11.30	2.85

Coal mixture :

Imported coal 35%   Charfines 5%   Indian coal 60%

Coal analysis :

Moisture 4.18%	Volatiles 26.14%
Ash 28.42%	Fixed carbon 41.26%
SO_3 1.80%	Calorific value 4942 kcal/kg

Clinker :

The range of clinker analyses quoted by the works is as follows :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
20.94-21.76	4.98-5.80	3.02-4.37	64.55-67.75	1.90-2.20

RAMASAMYRAJA NAGAR CEMENT WORKS

Personnel who participated in discussions :

Mr P R Ramasubrahmaneya Rajha	Chairman and Managing Director
Mr R Natarajan	General Manager
Mr S N Rama Raju	Administrative Manager
Mr V Jagannathan	Works Manager
Mr H V Sethuram	Chief Mines Superintendent
Mr K S Anandhan	Mines Superintendent
Mr R Murugan	Supt. Process & Quality Control
Mr A Velayuthan	Works Engineer
Mr S Natarajan	Process Control Engineer
Mr A Rama Krishnan	Chief Burner
Mr S Shanmugam	Chief Geologist
Mr Natarajan	Assistant Quarry Manager
Mr R Subramanian	Head Burner
Mr T Rajagopal	Chemist
Mr R Ramalingam	Shift Chemist
Mr S Chokkalingam	Shift Chemist

Names of NCB counterparts :

Dr M M Ali	Chemist
Mr U R Raju	Geologist

Annex 7

SHRIRAM FERTILISERS AND CHEMICALS
KOTA CEMENT WORKS
(Rajasthan)

This 200,000 tpa wet plant was designed and built to utilise the calcium hydroxide waste sludge from the acetylene generator operated by the company. The original scheme involved the use of a settling tank to separate the sludge from a suspension containing 94% moisture. However this tank was never constructed and material containing 30-60% moisture is excavated from the natural settling ponds into which the acetylene plant discharges its waste. Water is added to the sludge to increase the moisture content to 65-70% and this slurry is then blended in the wet-mill with limestone and iron ore. The final slurry has a moisture of about 42%. Half the limestone is obtained from the company's own quarry, situated about 40 km from the works, the remainder is supplied by a contractor from a number of sources.

Problems reported by the works :

1. The thixotropic nature of the slurry causes considerable handling difficulties despite the high moisture content. Sedimentation and solidification in the blending tanks results in them having to be dug out by hand at frequent intervals.
2. Spillages at the back-end of the kiln are frequent.
3. Rings in the kiln and brick damage result in very frequent stoppages of the plant.

The limestone quarry : The quarry is a new one having been opened up to supply the works. The exploration was carried out by the geological department of the Associated Cement Co. Ltd. Diamond core drilling was carried out but the core recovery was not adequate, ranging from 39% to 97% but averaging only 79%. This fact was apparently realized and a series of 'down the hole hammer' (DTH) boreholes was put down to obtain complete samples. Unfortunately this technique is unsuitable for accurate sampling and therefore the results cannot be considered valid. However on the basis of the DTH results 'correction factors' were applied to the analyses of the samples obtained from the core drilling and the deposit assessed. It was divided into blocks, apparently on the basis of apparent uniformity between boreholes. The quarry plan is based on these blocks. The technique used cannot be considered as satisfactory for the accurate assessment and development of cement raw materials. Visual examination of the quarry also indicates inaccuracies in the geological assessment. The limestone beds, which are on average about 30 to 50 cm thick where exposed, are all separated by clay bands, the clay making up about 10% of the deposit. These clay bands are not often indicated in the borehole logs and it is probable that the high core loss could be due to loss of clay during drilling. The analyses upon which the raw material assessment was based will not be the same as those obtained from the quarry since both limestone and clay are transported to the works. This hypothesis tends to be supported by the fact that a high chemical variation is experienced in the limestone received from the quarry, the lowest quality stone always contains more alumina and iron as well as silica, indicating clay minerals, than would be expected from the ACC report. This high content of clay results in a limestone analysis which is not particularly suitable for use in cement manufacture and removal of the clay should be considered. Grab samples of both limestone and clay are to be analysed by the NCB, the mineralogy of the clay will also be investigated since this could affect the viscosity of the slurry. The present quarry is fairly shallow and it is planned to start the second bench shortly. It is suggested that every effort be made to develop the quarry rapidly to a position where it is regular in shape, accessed by an access ramp and with a slightly sloping floor allowing drainage to a sump equipped with a pump for use in the wet season. The limestone is transported to the works by road, often of poor quality. The Boondi limestone is supplied by contractor from, it is believed, three sources. The quality must be monitored by sampling (see below) and should variation occur, this should be minimised by specifying the quality as well as the quantity of stone to be delivered. High-grade limestone chips, waste from the carbide plant feed, are also available.

The works : Crushing of all the materials is undertaken at the works. All the stone is passed through a double toggle jaw crusher which reduces it to -150 mm. A double-deck screen with 50 mm and 19 mm screens allows the fine material to by-pass the secondary cone crusher. The product from the secondary crusher is returned to the screens thereby creating a re-grind circuit. There is no method of screening out fine, potentially low-grade, material in the circuit. Thus all the material fed to the crusher enters the process. It is essential therefore that the quality control of the raw materials is controlled before the crusher. At the time of the visit the high-grade limestone chips were seen to be very contaminated with clay and dirt, the overall composition could have been well below that intended. It should be appreciated that the quality of material required for cement manufacture is equally as high, if not higher, than that required for carbide production. If high-grade limestone from the chemical plant is to be used for cement manufacture it must be a clean and uniform material. The linear blending bed was being used, at the time of the visit, as a stockpile. Batches of different types of limestone were observed on the heap. This will result in uncontrollable variation when the material is reclaimed. Sampling of the stone being fed to the pile is completely inadequate, being performed by hand. Stone being delivered to the works by haulage contractor goes directly to the crusher and then the stockpile, it is therefore completely uncontrollable. A more systematic system must be introduced. The blending bed must be used as such. It must have a target grade. To accomplish this an automatic sampler, preferably of the swinging arm type (Annex 4), must be installed. Only the Nimoda limestone should be fed directly to the crusher, all other components should be stockpiled prior to the crusher and fed to the blending system in a systematic manner thereby allowing complete control of the stockpile composition. This stockpiling prior to crushing could be accomplished by tipping in a regular manner to form a bed, flattening this bed, sampling of the flattened surface and then tipping further loads on the flattened surface. The procedure is repeated until a layered heap is constructed. Extraction of the stone from the heap would be by wheeled loader in a systematic manner from one end. As the target composition of the kiln feed is known together with the sludge composition, the target composition of the blending bed can be calculated. It is essential that the supplies of stone are adequate to ensure that the stockpile of target grade can be constructed. The sludge is worked by contractor and delivered to the works by him. There are reports that this system fails from time to time and the slurry has to be prepared from limestone alone. This is completely unsatisfactory since the handling, slurrying and burning characteristics of such a blend will be completely different to one utilising sludge. A regular supply of sludge must be available since the proportions of limestone and sludge must remain constant. It is also noted from the data supplied by the works that the analysis of the sludge varies; a range of 9% CaO was noted for one month. As the sludge deposit is layered, systematic working by the contractor of one face in the deposit should remove this variation and efforts should be made to accomplish this. High chloride ESP dust is being discharged to the sludge settling ponds, this could cause a problem in due course when the material is used. Consideration should be given to treating the dust in some other manner, for example nodulisation, and tipping elsewhere.

The limestone and sludge are fed to the mill where the limestone is ground and the mixture homogenized. This system will produce poor results since the already very fine sludge will make milling inefficient, leading to either a very high residue or high power consumption. When the economics of the plant permit, consideration should be given to dry milling of the limestone followed by mixing with the sludge. The actual mix used to make the slurry can contain up to five components, Nimoda limestone, Boondi limestone, high-grade limestone chips, sludge and iron-ore. This is considered to be an excessively complex mix and it may be possible to rationalize this.

Slurry blending and storage is undertaken in two inter-linked slurry basins, each equipped with a rotary harrow and air-agitators. The design of the equipment would appear to be inadequate for the task of blending the rather thixotropic slurry. The two harrows, at the bottom of the tanks, are fitted with air jets on their leading edges. The harrows themselves are so massively constructed that a build-up of solidified slurry develops on them. As a result the material in the base of the tanks is rotated en masse as the harrows rotate. Eventually due to lack of agitation all the slurry becomes solid in the base of the tanks and they have to be stopped and dug out by hand. Although at the time of the visit one tank was empty and the other low, exposing the build-up on the harrow it could be anticipated that the thixotropic nature of the slurry would result in little agitation by the air and no homogenisation at all. The output from the tanks could therefore be variable, but as only one sample per day appears to be taken for analysis, the actual variation is unknown. The system is clearly unsatisfactory and modification of the tanks to a design using a top mounted rotor dragging chains and harrows through the slurry, as well as injecting air, should be considered. The kiln was down for repairs at the time of the visit, a ring having formed in the burning zone. Inspection of the kiln indicated that apart from the ring no coating at all existed in the burning zone. The ring itself consisted of a glassy vesicular mass which had fused with the refractories. Beyond the ring the bricks were so badly damaged that the kiln shell was visible. The outside of the kiln showed extensive scorching in this area. It is clear that serious control problems exist, these are probably due in part to variable kiln feed and coal quality, however the frequent stoppages of the kiln, often with refractory problems, suggests experience in kiln control is probably also lacking and the assistance of the NCB should be sought in this area. The back-end of the kiln suffers from spillages of slurry. A smoke-box is fitted and this fills with slurry from time to time. Originally the back-end diameter was small but as this was causing ID-fan problems it was increased; this has not helped the problem of spillages. The slurry feed-pipe discharges almost at the base of the kiln and very close to the end. The first 5 metres of the kiln are devoid of any fittings, there being no chains or lifters, so that there is nothing to assist the thixotropic slurry away from the feed pipe. It is considered that it may be worth considering reducing this initial un-chained part of the kiln to a length equal to one kiln diameter and experimenting with a spiral chain system which will tend to screw the slurry down the kiln; it may also be worth while considering some form of lifter to assist in moving the slurry away from the end of the kiln. Fittings of this type will also improve heat transfer in this area. The coal supply is reported to be relatively good only a small variation in ash content occurring. Even so a visit to the coal store indicated that some heaps contained iron pyrites and others pure white sandstone. Systematic sampling and extraction of the coal in a manner similar to that described above for the limestone stockpiles is recommended. This is especially important since coal ash may contribute between 5% and 6% of the raw material mix.

The overall impression gained from the visit to this works is that it is experiencing considerable difficulties at all stages in the manufacturing process. Despite the competence of the management team, they lack, with a few exceptions, practical experience in the manufacture of cement, especially in the area of kiln control and burning. The NCB may be able to provide assistance in this area. There is currently little or no control of the slurry preparation, a problem which is probably compounded by the fact that the XRF-analyzer is not yet operational. It is likely that the problem of handling a material as thixotropic as the slurry will always exist. However before detailed investigations can be carried out on such problems as rings and brick failure, it is essential that careful working, storage, blending and sampling of the materials, leading to a consistent kiln feed, are achieved. Only when feed-forward control of the slurry composition is introduced can such uniformity be achieved. Moreover chemical control by sampling must be used to enable accurate construction of the stockpile to be undertaken so that the ratio of stone to sludge is always constant.

Recommendations.

1. Consideration should be given to removing the clay horizons in the Nimoda limestone at the quarry using some form of simple screen or grizzly. If it is found on analysis that the clay could be beneficial to the process it could be returned to the process in a controlled manner.
2. The quarry should be developed in a more regular manner, the total area currently worked should be excavated to the full depth of the first bench and accessed by means of a suitable ramp. Proper quarry development plans should be drawn up for both one and five years. The quarry floor should be sloped away from the face and towards a sump fitted with a pump for use in the wet season.
3. The quality, as well as quantity, of the Boondi limestone should be specified to the contractor supplying it.
4. If high-grade limestone chips are to be supplied from the carbide plant they must be clean and uniform.
5. Only the Nimoda limestone should be fed directly to the crusher. All other materials should be stockpiled and fed to the system as required.
6. An auto-sampler, preferably of the swinging arm type (Annex 4), should be installed on the feed belt to the stacker.
7. The blending bed should have a target composition using recommendations 5 and 6 to accomplish this.
8. The stockpiles of materials other than Nimoda limestone could be achieved by systematic tipping to form a layer, which after flattening and random sampling, is used as the base for the next sequence of regular tipping. In this manner a layered heap of known composition can be built up.
9. The ratio of limestone to sludge in the mix must be constant. Failure on the part of the contractor to deliver sludge cannot be tolerated if stable plant conditions are ever to be achieved.
10. Working of the sludge must be methodical to ensure that variations in quality do not occur.
11. Alteration of the slurry tank blending system to one using a rotating

gantry pulling chains and harrows through the slurry, as well as injecting air, should be considered.

12. Slurry sampling should be carried out hourly to ensure that a uniform feed is being despatched to the kiln.
13. Practical assistance in kiln control should be sought from the NCB. It appears unlikely that the frequent damage to the burning zone can be attributed to variable feed and fuel alone.
14. Consideration should be given to reducing the initial 5 metre unchained part of the kiln to a length equal to one kiln diameter and experimenting with a spiral chain system which will tend to screw the slurry down the kiln; it may also be worth while considering some form of lifter to assist in moving the slurry away from the end of the kiln.
15. Stockpiling the coal using systematic tipping to form a layer, which after flattening and random sampling is used as the base for the next tipping sequence, will enable a blended coal stock of known characteristics to be built up. Extraction in a methodical manner from one end of the pile would ensure a high degree of uniformity.
16. Consideration of the raw materials analyses supplied by the works indicates the possibility that a mix containing less components could be achieved. However the availability of sludge is such that a limit has to be placed on its consumption, a figure of 25% being preferred by the works. The maximum quantity of high-grade rejects which are available is reported to be 20 tpd, this is such a small addition to the 1000 tpd raw meal requirement that it can be ignored in any calculations. The chemistry of the various components is such that in order to produce a clinker with a high LSF giving good strength characteristics, a high sludge content is required to compensate for the high ash addition experienced in the wet process. Thus a balance between sludge addition and cement properties has to be made. The situation can be improved by using a either pure Boondi limestone or a blend of Nimoda and Boondi. For example calculations suggest that a

mixture of equal parts of clean screened Nimoda limestone and Boondi l tone, when blended with sludge in the ratio :

Limestone mix : sludge = 77 : 22.4

a clinker with an LSF of 0.98 and a silica ratio of 2.4 is possible. The remainder of the mix would be iron ore. Such a calculation assumes an ash adsorption of 80% which would require fine grinding of the coal as well as very careful control of the burning conditions in the kiln. The addition of more Boondi limestone enables the sludge addition to be reduced slightly. However if the Nimoda limestone is taken as dug and not screened the sludge requirement exceeds 30% even when large quantities of Boondi limestone are used.

KOTA CEMENT WORKS

Information collected

Raw materials :

Typical analyses of the various limestones as received at the works are as follows :

Nimcda limestone :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	%CaO	%MgO
10.88-21.00	2.12-5.30	2.00-3.62	35.10-44.86	1.06-2.20

Boondi limestone :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	%CaO	%MgO
9.86-28.10	2.38-10.62	1.20-3.68	32.10-47.04	1.40-1.94

High-grade limestone chips :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	%CaO	%MgO
2.80-4.50	0.60-0.90	0.32-0.48	51.72-53.50	nil-0.14

The variation in the composition of the sludge is reported as follows :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	%CaO	%MgO
5.94-12.20	0.54-2.36	0.08-0.56	50.10-62.16	-

The variation in the composition of the iron ore is reported as follows :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	%CaO	%MgO
6.72-14.48	8.10-13.90	68.00-73.60	0.53-1.30	-

Coal :

The ash content of the coal range varies between 20.06% and 37.05%

Slurry :

The range of slurry analyses quoted by the works is as follows :

% SiO_2	% Al_2O_3	% Fe_2O_3	% CaO	% MgO
11.26-13.10	2.32-3.92	1.92-2.60	44.25-48.55	1.12-1.40

Clinker :

The range of clinker analyses quoted by the works is as follows :

% SiO_2	% Al_2O_3	% Fe_2O_3	% CaO	% MgO
21.32-24.80	5.16-7.04	2.88-4.40	60.32-65.15	1.34-2.48

KOTA CEMENT WORKS

Personnel who participated in discussions :

Mr Rajiv Sinha	Chief General Manager
Mr Baljinder S Dua	General Manager
Mr P B Dixit	General Manager
Mr Arjun Dasgupta	Works Manager

Names of NCB counterparts :

Mr V K Arora	Chemical Engineer
Mr Imran	Geologist

Annex 8

CEMENT CORPORATION OF GUJARAT LTD.
SIDDHIGRAM CEMENT WORKS (VEREVAL)
(Gujarat)

This 3,300 tpd plant is a joint venture involving private industry and the Government of Gujarat. The F L Smidth two-string pre-calciner kiln was completed and started producing clinker in March 1988. Problems with the raw mill then stooped production for two months. Due to the fact that the quarry is not developed, the crusher prone to blockages, the blending bed not commissioned and the mill-feed silos continuously blocking, the works was only producing up to a maximum of about 800 tpd at the time of the visit. From analyses which were available it was seen that the C_3S content of the clinker is only about 36% and the C_2S content about 33%; acceptable cement strengths were obtained by fine grinding in the cement mill. The coal stacker/reclaimer will not be completed for a further twelve months. The management team appeared to be resigned to the fact that full production will not start for some time. However a more positive approach is required to solve the many problems which are apparent in the preparation of the raw materials. These problems are related to the fact that the choice and/or design of the raw materials handling plant is not ideally suited to the raw materials. It would seem possible, although not proven, that the raw materials sent to the various manufacturers for design purposes were not representative of the deposit as a whole.

Raw materials : The main raw material is a limestone which occurs at outcrop over much of the area around the works. The age of this deposit is unclear and may either be Pleistocene or Pliocene/Miocene. Rocks of this latter age occur extensively in the area and associated strata often contain gypsum. The limestone was investigated in 1982 by the Department of Geology and Mineral Exploration of Chowgule and Company Private Ltd., Goa. The drilling was undertaken using NX-size equipment and the overall core recovery was reported to be 87%, which although moderate is not really adequate for an industrial mineral investigation. The core descriptions are inadequate and even the identification of a 'marl' beneath the limestone is surprising since the present excavation show the underlying strata to be a calcretised brecciated impure limestone, or kunker. Approximately every half-metre of core was analysed for total carbonate and then groups of samples analysed for silica, alumina, iron, calcium and magnesium. In the early boreholes trace elements such as chloride were checked, but not in the majority of the cores. Unfortunately when the total carbonate calculated from the bulk analyses is compared with the appropriate weighted averages of the individual total carbonates, large discrepancies can be found. The reason for this is unknown, it could be due either to poor sample preparation or poor analyses. As well as core drilling, DTH boreholes were also drilled in order to allegedly determine the quality of the quarry product; this procedure is not a valid one and should not be used. The assessment of the deposit undertaken by the consultants is, in terms of a cement raw material deposit, rather inadequate and could, if not used with care, lead to misleading conclusions. Despite the inadequacies of the original borehole data, this information should be used to re-assess the deposit and prepare long-term, five-year and one-year quarry development plans. The services of the NCB could probably be of value in this exercise since it is considered that the quarry personnel are probably not sufficiently experienced to undertake what is a fairly complex chemical assessment.

Visual inspection of the initial quarry development indicates that the limestone is basically a semi-lithified shallow water deposit, in which patches of have become rather more cemented and form harder 'blocks' within the main mass. The top surface outcrop of the stone is invariably lithified forming a hard crust, or pan, at surface level. The limestone appears to rest disconformably on variable calcrete which in turn passes down into the Gaj Clay. All the strata are highly variable both chemically and physically, horizontally as well as vertically. The assessment by the consultants, and upon which the present quarry plans are based, suggests that the strata are relatively uniform; this conclusion is considered suspect.

The nature of the strata, together with their close proximity to the coast would suggest that chlorides and sulphates could be present. The early analyses of the core tended to support this view, despite the fact that the drilling fluid used was water which would dissolve and therefore reduce the concentration of such salts in the core. Later boreholes were not analysed for these potentially harmful elements. Problems may be encountered in the kiln cyclones in due course if sulphates and/or chlorides are present in any quantity.

Extraction of the raw materials : At present the quarry consists of about four or five separate excavations. Although a conceptual quarry development plan appears to exist, it is not being achieved. Moreover the plan which does exist appears to be based on an inadequate reserve assessment and is apparently controlled more by logistics and topography than the chemistry of the raw materials. A much more positive approach must be made to the quarry development if the required quantity of stone, with the correct chemical composition, is to be supplied to the works once it comes fully on stream. The drilling and blasting is currently not good. It must be emphasized however that as the quarries are still very shallow and the stone is very variable, consisting of hard and soft stone, good fragmentation of the hard stone with the minimum powdering of the softer material will be difficult to achieve. Expert advice, possibly from the explosives manufacturers, should be sought. The quarry plant, consisting of two excavators, one wheeled loader, three drills (but only two compressors), five dump trucks and two bulldozers, should be just adequate to supply the works when operating at full capacity. However this will only be true if maintenance is good and the availability of the mobile plant is at least 85%; good quarry practices are therefore required. Whether or not drilling and blasting is the correct method of extraction for the limestone is debateable since ripping the stone might also be possible. If this was undertaken down an incline and the ripped stone then bulldozed to the base of the slope for loading a certain amount of blending would result. Whether or not this method of extraction is feasible, and whether it would result in a greater or lesser quantity of fines would have to be determined by experiment.

Crushing : The Hazemag impact crusher is reported to block from time to time. This is not surprising since, although little fine material is present in the raw material, blasting generates a certain amount of fine, water-absorbent material which will compact especially in the monsoon season. The hydraulic feeder will tend to compact these fines thereby blocking the crusher. A grizzly, either at the crusher or in the quarry is required to allow the undersize material to by-pass the crusher.

The soft nature of the limestone and the production of fines at various stages in the process appears to be the major problem in the raw materials circuit. It is considered that the impact crusher could be contributing to this problem. The impression which was gained during the visit was that considerably more powdery fines were coming out of the crusher than were going into it, much of the stone appears to be pulverized rather than being merely crushed. Experiments using a fines-free feed of clean limestone boulders have been suggested to determine the extent of the problem. Adjustments to the impactor-plates and grinding plates should be made to minimise the production of fines. If minimum fines results in too much over-sized material, a re-grind circuit will be required.

Blending-bed : This has not yet been commissioned. It is a simple linear stacker/reclaimer system providing only chevron-type piles. This is unfortunate since the mixture of coarse and fine particles which will always exist in the raw materials ideally require a windrow stacking system.

Milling : The mill-feed hoppers block continuously in the monsoon season. The reason for this is probably a combination of intermittent feeding, too many fines and possibly segregation due to a complicated feed chute. The hoppers are currently run virtually empty thereby allowing considerable free fall of the material within the hopper. Very large pieces of limestone are also present which can cause potential blockages on the weigh-feeders. It is considered that once the fines are minimised, the lump size of the limestone reduced to the design size and the blending bed is functioning, the intimate mixture of stone and fines will flow reasonably well. Should this not be the case then the possibility of adding vibrators to the hoppers may have to be considered.

Should problems of blockages persist, it may be possible to include a hammer mill drier in the circuit. This would be an expensive solution especially as it may be necessary to install an auxiliary furnace, the calorific value of the fuel being so low that the surplus heat in the kiln gas-flow may not be adequate to dry the material.

The mill itself had problems of instability and it is reported that FLS recommended increasing the maximum size of the lump stone. This has apparently helped the mill but has possibly added to the problems of the feed hoppers. Once again the effect of reducing the quantity of fines produced in the quarry and the crusher could well be very beneficial.

Kiln : Since there are problems with the raw materials and also variable fuel, due to the fact that the coal blending facilities will not be available for a further twelve months, it is not considered that valid data are available for the kiln. The only observation which could be made at the time of the visit was that sandstone was being added to the raw materials mix in order to raise the SR to an acceptable level. This is considered surprising since the geological report indicates that the silica content of the limestone is inherently high giving rise to high silica ratio; the accuracy of the exploration data is therefore in question.

Control : Two raw materials sampling devices have been incorporated in the works design, one located before the blending bed, the other after the reclaimer. The latter has not been installed and is lying on the ground close to its (presumed) intended position. The former has been partly installed but cannot be used since the sample chute has been blocked off. However the design of the sampler, a narrow chute which passes horizontally through the raw material stream at a transfer point, is not suitable for either the particle size, quantity or physical nature of the material and would never give a representative sample. Both samplers should be replaced with swinging arm sampling devices (Annex 4).

Recommendations.

1. Using the existing borehole data, the raw materials deposit should be completely re-assessed. It is necessary to prepare accurate grade-plans for each bench and then prepare a long-term quarry plan, together with a detailed five-year plan and a very specific one-year plan. The NCB should be consulted regarding this assessment.
2. Further exploration drilling should be undertaken close to known borehole sites, using wide diameter coring tools with air as the flushing medium. Borehole core recovery in excess of 96% each and every metre is essential. This will enable the accuracy of the initial drilling to be determined. Accurate total analyses, including trace elements, especially sulphate and chloride, should be undertaken.
3. A much more positive and organised approach to quarry development must be made. A single quarry developed to its full depth is required as soon as possible.
4. The standard of blasting should be improved to give better fragmentation of the hard rock and minimum powdering of the softer material. Advice from the explosives manufacturers should be sought.
5. A grizzly is required to allow undersized material to by-pass the crusher and thereby minimise the problem of blockages in the crusher.
6. Using a feed of clean, fines-free, limestone boulders only, the extent to which the crusher is pulverizing the soft limestone should be investigated. The impactor-plates and grinding plates should be adjusted to minimise the production of fines. If this results in too much over-sized stone a re-grind circuit comprising a screen and return belt will be required.
7. The raw materials samplers, one of which is partially installed, will not adequately perform the task for which they were intended. They should be discarded and replaced with swinging arm type samplers (see Annex 4). The sampling frequency, probably about once every five minutes, to give a composite hourly sample, should be determined by experiment. Sample reduction at the sampling stations is best done by hand using laboratory sized hammer-mills and correctly sized riffles.

8. Should materials handling problems persist once all parts of the raw materials preparation circuit are functioning correctly, it may be necessary to install a hammer mill drier. This could require an auxiliary furnace.

SIDDHIGRAM CEMENT WORKS

Information collected

Exploration :

Core drilling :

Grid	No. of holes	Total metres
500 m	17	453.5
200 m	34	686.0
100 m	18	362.0

DTH drilling :

	27	308.0

Average core recovery 86.9%

Raw materials :

Typical analyses of the various limestones are as follows :

High-grade limestone :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	%CaO	%MgO
5.0-10.0	2.0-3.0	1.0-2.5	46.0-51.0	0.5-0.8

Low-grade limestone including 'marl' :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	%CaO	%MgO
15.0-20.0	3.0-3.5	2.0-3.5	37.0-42.0	0.6-0.8

Overburden clay :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	%CaO	%MgO
35.80	11.38	8.22	19.84	-

Sandstone :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
75.0-90.0	2.0-7.0	2.0-5.0	1.0-2.0	-

Laterite :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
10.0-20.0	12.0-18.0	45.0-55.0	1.0-2.0	-

Coal :

	Australian coal	Indian coal
Moisture %	2.0-2.5	1.5-2.0
Volatiles %	22-28	25-30
Ash %	10-15	30-35
Fixed carbon %	55-65	35-40
Cal. value kcal/kg	6000-7000	4000-4500

Ash analysis (Australian coal)

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
55.60	27.55	5.85	8.82	-

Kiln feed :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
11.0-12.0	3.0-3.5	2.5-3.0	44.5-45.5	0.5-0.8

Clinker :

$\%SiO_2$	$\%Al_2O_3$	$\%Fe_2O_3$	$\%CaO$	$\%MgO$
20.0-22.0	6.5-7.0	3.3-3.8	63.5-65.0	0.8-0.9

SIDDHIGRAM CEMENT WORKS

Personnel who participated in discussions :

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Mr M D Joshi	General Manager (Operations)
Mr S K Jain	Dy. General Manager (Production)
Dr R K Sood	Manager (Quality Control)

Names of NCB counterparts :

Mr K I Romi	Mining Engineer
Dr M Vasudeva	Chemical Engineer