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MINI-CEMENT TECHNOLOGY

by

Harro Taubman

MINICEMENT TECHNOLOGY

REPORT ON A
MISSION SPONSORED BY APPROPRIATE TECHNOLOGY INTERNATIONAL
TO LUCKNOW

FOR

ASSESSMENT OF THE MOHANLALGANJ MINI CEMENT PLANT
FROM APRIL 10 TO APRIL 20 1985

Participants of the Mission

Marshall Bear (ATI)
Frank Almond (ITDG)
Harro Taubmann (BST)

Author: Harro Taubman
Rheinfelden: April 25 1985

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ANNEX I TERMS OF REFERENCE

ANNEX II CLINKER ANALYSIS AND COMMENTS

SUMMARY

The objective of the mission, to appraise the lay-out and the operational conditions of the Mohanlalganj plant, was achieved by inspecting the plant and by making comparisons with technologies employed at two other mini cement factories:

One, near Gwalior, a 100 t/d plant built by Movers (P) Ltd, the other near Sultanabad a 20 t/d plant, built by Saboo (P) Ltd.

The Mohanlalganj plant has proved that Portland cement can be produced with marl as the basic raw material, in a VSK using the intermixing technology, ie raw material and fuel are ground separately and mixed just before the nodulizer.

Due to a variety of deficiencies, such as:

- frequent power cuts,
- labour and management problems,
- design and lay-out defects,
- operational irregularities,
- raw material variations,

The plant up to now has not proven it's reliability and economic performance.

Although the break-even point is below 500 t/month, it has not yet been reached, and therefore the pilot plant operation is running at a deficit.

During the experts visit a few improvements were suggested. Drawings and descriptive notes are available at the plant-site.

Due to problems in the raw material supply during the monsoon period it is recommended to stop the plant, install the suggested improvements and try again after the monsoon in a 4 weeks test to get the plant operating profitably.

I) OBJECTIVES OF THE TECHNICAL MISSION

As defined in the Terms of Reference (Annex 1) the objective of the technical part of the mission was to evaluate the lay-out and the achievements of the Mohanlalganj mini cement factory under the control of ATDA (Appropriate Technology Development Association), Lucknow, with a nominal capacity of 20 t/d of clinker.

II) METHODOLOGY

In order to fulfil the objectives the factory at Mohanlalganj was visited several times and the operational conditions were examined thoroughly. The work included a detailed appraisal of the available drawings, technical descriptions, notes and lay-out parameters, the analysis of the production reports and the control of the operational conditions of the individual machines and equipment.

In connection with this report also the reports of Mr M Bear (ATI), Mr F Almond (ITDG) and the report of Mr S Sinha (EDA) have to be considered.

III) PLANT DESCRIPTION

A) General Comments on Cement Technology

Conditions for the production of Portland cement:

1) The raw meal must be sufficiently finely ground and homogenized;

2) The burning process must be controlled in such a way as to complete the reactions and the production of the clinker phases;

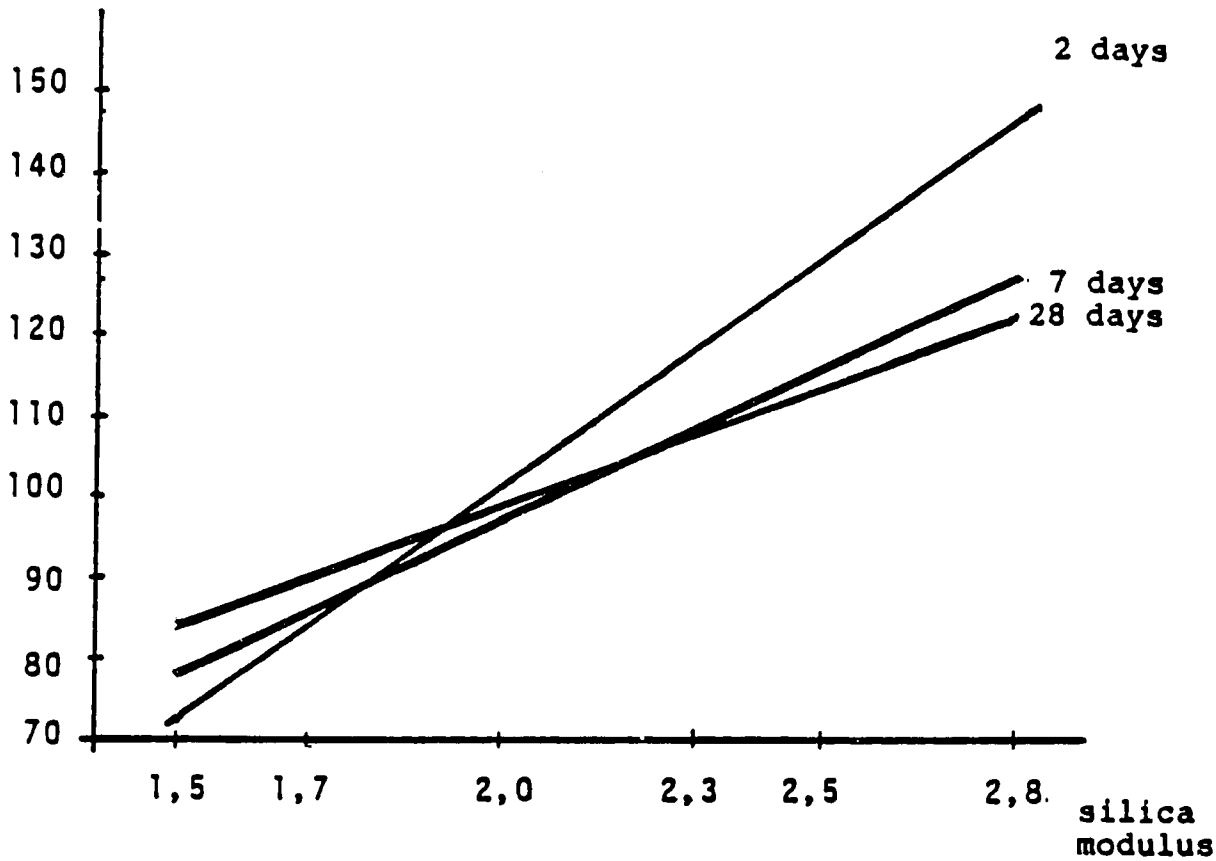
3) The cement grinding has to be completed in such a way as to produce consistently reactive cement when adding the same amount of sulfates (gypsum).

Generally it has to be stated that burning in a rotary kiln is easier than in a shaft kiln. When shaft kiln technology (VSK-technology) is demanded, as is the case for small scale cement factories and even more for mini cement factories (below 200 t/d), the raw material mix has to be prepared in such a way as to guarantee trouble-free operation of the VSK (no jamming) and to produce at the same time a cement clinker which can give the necessary compressive and bending strength. Therefore a high lime standard is necessary.

In connection with these general comments see also the following figures and tables indicating the influences on the compressive strength of the different moduli. The basis for the relative compression strength is a laboratory cement with the following parameters:

LSF	95
Silica modulus	2,0
Alumina modulus	2,0

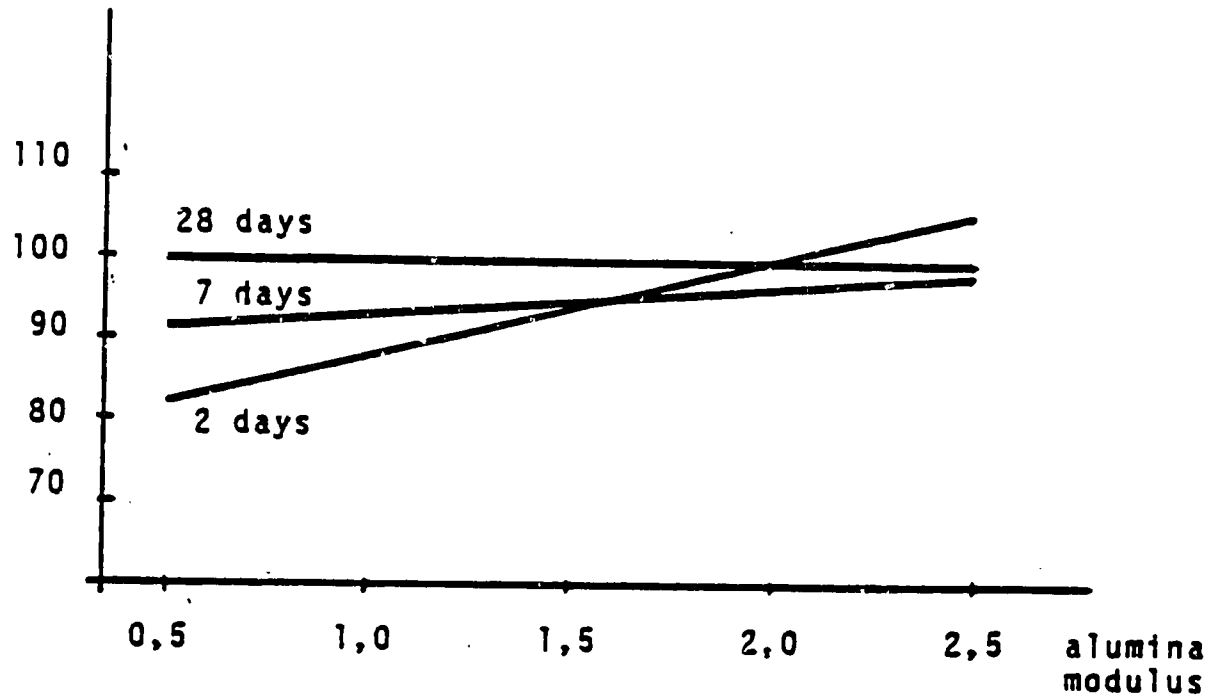
In Fig 1 and in the corresponding Table 1 the influences of the silica modulus on the compressive strength and the clinker phases are represented:



Clinker phases, actual (% by mass)

Silica modulus	alite	belite	C_3A	$C_2(AF)$
1,5	50	19	21	10
1,7	54	17	20	9
2,0	58	16	17	9
2,3	61	15	16	8
2,5	63	14	16	7
2,8	65	14	15	6

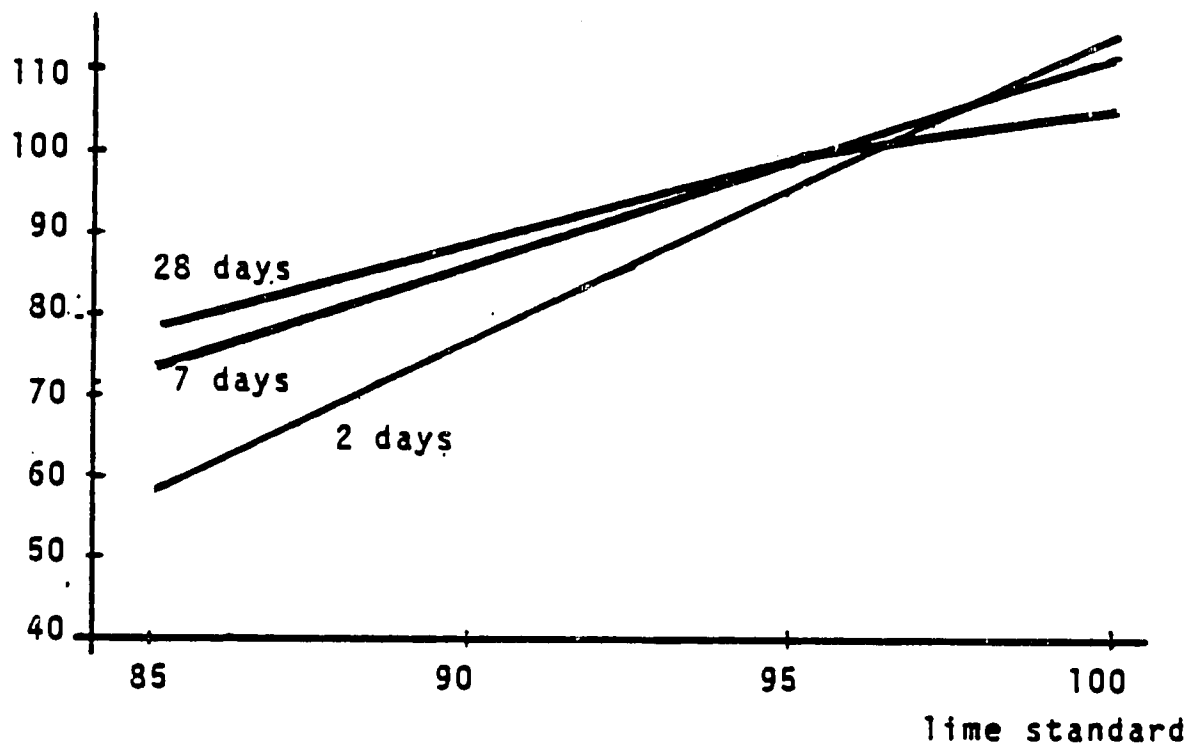
Fig 2 and the corresponding Table 2 show the relative compressive strength and the clinker phases as a function of alumina modulus (AM).



clinker phases, actual (% by mass)

alumina modulus	alite	belite	C_3A	$C_2(AF)$
0,5	68	14	0	18
1,0	65	14	6	15
1,5	63	15	10	12
2,0	58	16	17	9
2,5	56	16	20	8

Fig 3 and Table 3 are representing the influence of the lime standard (65) on the relative compressive strength.



clinker phases, actual (% by mass)

lime standard	alite	belite	C_3A	$C_2(AF)$
85	39	37	15	9
90	50	28	15	9
95	58	16	17	9
100	69	4	17	10
105	71	0	17	9/3 CaOfr

B) Raw Materials

The normal materials for cement production are limestone and clay. A typical raw meal mix is shown in Table 4.

Table 4 Typical raw meal mix

		average
CaO	60 - 90%	65%
SiO_2	18 - 24%	21%
Al_2O_3	4 - 8%	6%
Fe_2O_3	1 - 8%	3%
MgO	5%	2%
others	5%	3%

But of course the range of raw materials available for cement making is wide. Table 5 indicates some of the more important raw materials, and their carbonate content.

Table 5

Limestone	+ 95%	$CaCO_3$
Marly limestone	85% - 95%	"
Limy marl	70% - 85%	"
Marl	30% - 70%	"
Clayish marl	15% - 30%	"
Marly clay	5% - 15%	"
Clay	- 5%	"

If a policy of promoting decentralised manufacture of cement, through small shaft kilns, is adopted, then the use of locally-available raw materials can be maximised. The range of potentially suitable raw materials is wide.

C) The Raw Material Basis of Mohanlalganj Plant

The raw materials used in the Mohanlalganj plant are the following:

1) Marl:

SiO_2	8 - 10%
$CaCO_3$	75 - 85%
Al_2O_3	2,5 - 3,5%
Fe_2O_3	0,8 - 2,2%
$MgCO_3$	up to 4%
Water	8 - 20%

The Uttar Pradesh marls are a deposit formed by fresh water molluscs which lived in abandoned oxbow lakes (mort lakes) formed by the meandering of the mature rivers in the Indo-Gangetic plain. Since there has been little traditional use of these

deposits, and no significant exploration carried out, less is known of them than the lower quality kankars. Inferential information suggest that these types of deposit may be relatively widespread from Lucknow to Calcutta.

The relevance of this is that it is precisely in these densely populated alluvial plains that the usual materials for cement, hard rock limestone, are absent.

An exploration programme to evaluate marl occurences has been started. Marl occurs with widely varying carbonate contents. The best contain around 85% carbonate, and obviously allow lower grade materials such as kankar to be blended. Lower grade marls (around 65 - 75% tc) need limestone additions to bring them up to grade.

2) Kankar:

SiO_2	32 - 35%
$CaCO_3$	50 - 63%
Al_2O_3	6 - 8%
Fe_2O_3	3 - 4,5%
$MgCO_3$	up to 4%

3) Limestone:

SiO_2	6 - 8%
$CaCO_3$	86 - 93%
Al_2O_3	max 2%
Fe_2O_3	

4) Blue dust:

Fe_2O_3	90%

5) Gypsum:

$CaSO_4$	72 - 78%
SiO_2	8 - 12%
$Fe_2O_3 + Al_2O_3$	up to 2%

6) Coke Breeze:

NCV	4344 kcal/kg
ash content:	30 - 34%
volatile matter:	3 - 4%

Ash analysis:

SiO_3	15%
Al_2O_3	7%
Fe_2O_3	3,3%
$CaCO_3 + MgCO_3$	2%
$CaSO_4$	2,3%

7) SLV-coal:

NCV	4565 - 5470 kcal/kg
Vol m	11 - 14%
Ash content	21 - 23%
ash analysis:	Similar to coke breeze

8) Steam coal: for dryer heating

NCV	6000 kcal/kg
Vol m	30%
Ash content	18 - 20%
Ash analysis:	Similar to coke breeze

D) Raw meal composition:

During the experts visit the following raw meal composition was in use. (Figures given on LOI-free bases)

CaO	68,9%
SiO_2	20,2%
Al_2O_3	7,23%
Fe_2O_3	3,30%
LOI	36,40%

The fuel rate was reported to be 12.5% of raw meal weight. The fuel used is a 50/50 mixture of coke breeze and SLV coal, with a combined ash content of up to 30%. Including the ash minerals will modify the raw meal analysis in the following way:

CaO	66,54%
SiO_2	21,30%
Al_2O_3	7,82%
Fe_2O_3	3,58%

With those figures the different moduli can be determined:

Lime standard: $\frac{100\ CaO}{2,8\ SiO_2 + 1,1\ Al_2O_3 + 0,7\ Fe_2O_3} = 94$

Silica Modulus: $\frac{SiO_2}{Al_2O_3 + Fe_2O_3} = 1,87$

Alumina modulus: $\frac{Al_2O_3}{Fe_2O_3} = 2,18$

All the moduli are within the range of Portland cement required by the Standards, namely:

Lime standard	90 -102%
Silica modulus	1,8 - 3,0
Alumina modulus	1,3 - 4,0

One of the operational problems of the kiln is frequent sticking and jamming of the charge in the clinkering zone, probably caused by the chemistry of the raw meal mix giving rise to too great a liquid phase in the clinker. It has been shown above that including the fuel ash in the calculation results in a low LSF value of 94, reflecting the additional fluxing of the ash. Whilst the moduli are within the recommended ranges, and do give an excellent clinker, it is suggested that sticking could be reduced by either increasing the LSF ratio or increasing the silica modulus together with a reduction in the alumina modulus.

It is suggested that the following standards be tried in order to improve kiln operation:

LSF	97
SM	2,5
AM	1,94

See Annex II for a more detailed discussion of raw meal chemistry.

E) Plant Lay-out and Equipment:

The plant lay-out is shown in Fig 4. This lay-out allows the use of marl as the basic raw material.

The capacities computed for the different machines are based on the assumption that the kiln capacity is 20 t/d, and that for the production of 1 kg clinker 1,58 kg of dry raw meal are needed.

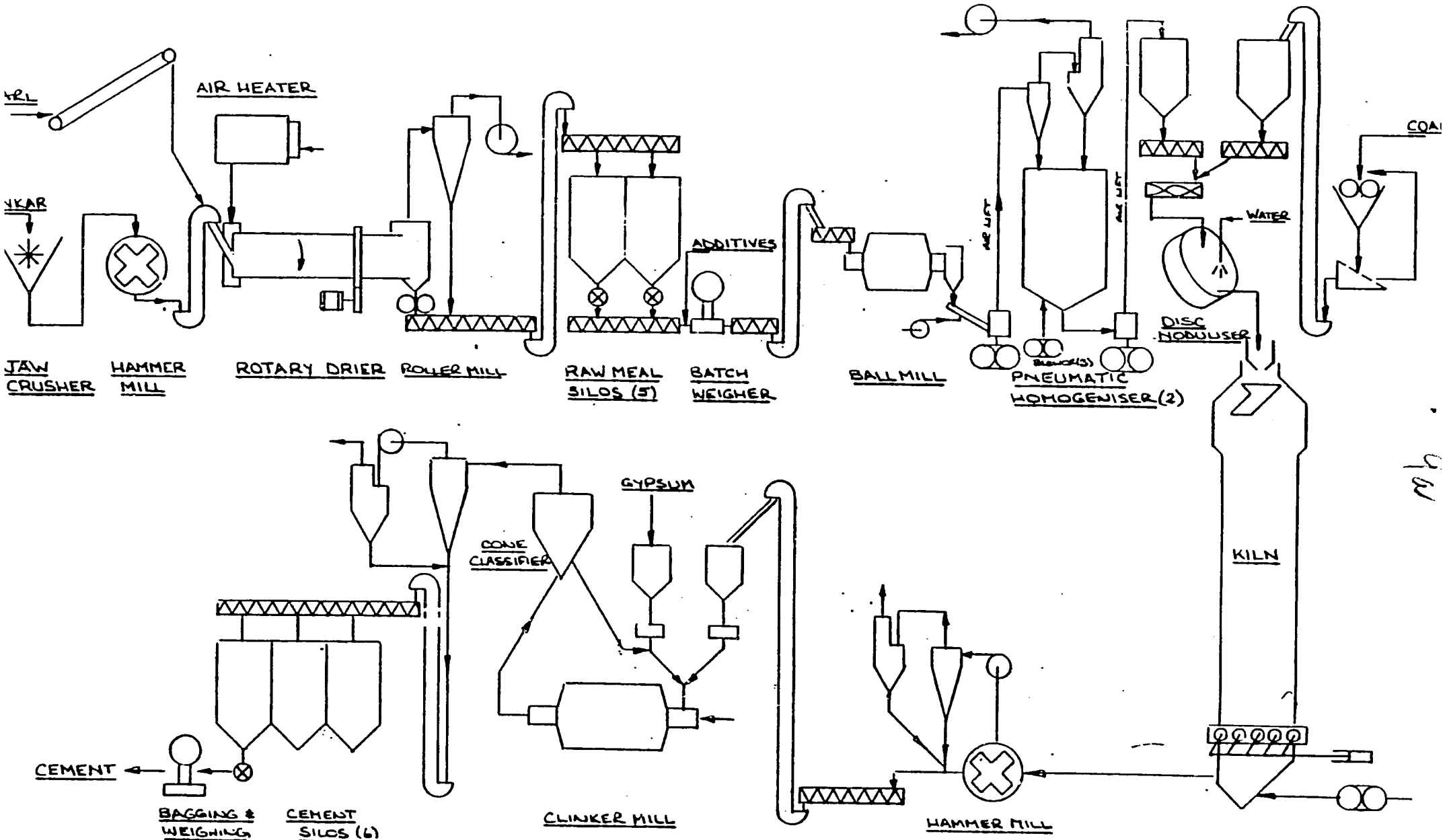
1) Rotary Dryer:

Dimensions: Diameter = 1,20 m
Length = 12,00 m
n = 11 rpm

Dryer capacity for a residual humidity of 0,5% H_2O: 360 kg/h of evaporated water.

Water to be evaporated:

With the assumption that 1,58 t of raw meal are necessary to produce 1 t of clinker and that dryer is operating 5 days with 3 shifts: ie 20 t.
7 = 140 t/week of the clinker = 221 t/week of raw meal; or $\frac{221}{120}$ = 1,84 t/h



INTERMEDIATE TECHNOLOGY DEVELOPMENT GROUP.	
DRAWN: FRA DATE: 5 APRIL 84 ED: 6 AUG 84	ATDA 25 TON/DAY MINI-CEMENT PLANT, MOHANLALGANJ. FLOWSHEET

Table 6

Capacity t/h (dry)	Humidity %	Water to be Evaporated kg/h	Coal Consumption kg/h
1,84 t/h	5	97	20,2
1,84 t/h	7,5	149	31,0
1,84 t/h	10	204	42,5
1,84 t/h	12,5	263	54,8
1,84 t/h	15	324	67,5
1,84 t/h	17,5	390*)	
1,53 t/h	17,5	324	67,5

*) When the humidity is higher than 15% the dryer has to be operated 6 days per week in 3 shifts, ie 1,53 t/h (dry)

So the dryer is big enough for the projected clinker production. Under monsoon conditions marl moisture content may rise to 18% or above , in which case the drier may not be entirely adequate when run for only 5 days/week (see Table 6). Extended running, or stockpiled dry material, should avoid this problem.

It is most important to maintain a continuous and regular feed. (1) *)

The beltconveyor, having a max capacity of 3,5 t/h, and the blower with a flow rate of 11,500 Nm^3/h are adequate for the desired production.

2) Bucket Elevators:

The various bucket elevators in the plant have produced a lot of operational problems. Therefore the capacity has been limited.

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*) The figures in parentheses relate to the suggestions in Table 9.

Each bucket can be fed with 0,37 kg of raw meal; there are 6.6 buckets per m of chain; the speed of the chain is 1,2 m/s;

Therefore the capacity is:

$$Q = 1,2 \cdot 6,6 \cdot 0,37 \cdot 3600 = 10.500 \text{ kg/h}$$

Large enough for the desired production. The problem is also here to maintain a regular feed. (2)

3) Storage Silos:

There are 5 storage silos provided on the raw material side. The dimensions are 2.4 m dia by 3.3 m high, giving an effective storage capacity of 15 m^3 per silo. The total capacity therefore is 75 m^3; enough for the production of 2 days and 8 hours. (3)

4) Raw Mill: (4)

The dimensions:

Inner diameter	1,35 m
Length	2,46 m
Grinding media	Steel balls, 5.38t charge

Ball diameter	%
60 mm	15
50 mm	15
40 mm	30
30 mm	40

Driving motor:	55 kW
Speed	27 rpm
Reported Capacity	2,2 t/h *)

Checking the capacity by Tovarovs formula:

$$Q \text{ t/h} = q \cdot \frac{a \cdot b \cdot c}{1000} \cdot 6,7 \cdot V \cdot D \cdot \frac{G}{V}$$

*) Information from plant manager.

q = specific mill capacity expressed in kg mill feed/kWh, ie 40 for raw meal mill

a	coefficients;	1,4 for marl
b	"	1,0 for 10% R/170 mesh
c	"	0,9 for 1 compartment mill

V = mill volume m^3

D = inside mill diameter m

G = total load of grinding media t

$$Q = 40 \; \frac{1{,}40 \cdot 1 \cdot 0{,}9}{1000} \cdot 6{,}7 \cdot 3{,}52 \quad 1{,}35 \cdot \frac{5{,}38}{3{,}52}$$

1,71 t/h

This indicates that the mill is just large enough, giving theoretically enough raw meal for 25 t/d of clinker if it is running 24 h/day, 7 days/week. This is not desirable, and a larger mill is really required. Also, if the mill is being fed at 2,2 t/h, undergrinding will result.

Poor grinding is also caused by the differential grinding of the marl and limestone. The harder limestone will resist grinding more than the marl, leaving a percentage of coarse particles of limestone in the meal. This could be avoided by batching the mill operation to pregrind the limestone, which could then be stored in a silo prior to mixing with the marl and regrinding. This would also require a larger mill capacity.

5) Homogenization: (5)

Two 80 t homogenizing silos are installed. These silos are operated by compressed air supplied by Rootes blowers.

The homogenized raw meal is fed to the kiln by pneumatic conveyors.

6) Nodulizer: (6)

Dimensions:	Diameter	1,68 m
	Speed	20 rpm
Nodule size:		8-12 mm
Water content:		12-13%
Capacity:		1,6 t/h

7) Vertical Shaft Kiln: (7)

Dimensions: Inner diameter 1,00 m
height 6,70 m
conical section angle 9°

Discharge: grate: oscillating 4 roller gate, with variable stroke.

max discharge volume 1,6 m^3/h

Blower: Rootes type: 1500 Nm^3/h, pressure 3000 mm WG.

The kiln capacity is supposed to be between 19 t/d and 21 t/d (nominal 20 t/d)

The amount of fuel added is about 195 kg/h.

In table 7 computed production figures for different diameters of kiln are given. The litre weight of the clinker produced is 1,1 kg/l.

Table 7

Dia m	Circ m	Area m	Circ/Area	Theoret Prod t/d	Nom Rate t/d
1,0	3,14	0,785	4,00	22	20
1,25	3,93	1,23	3,20	35	30
1,40	4,40	1,54	2,86	43	40
1,60	5,02	2,01	2,50	56	50
1,80	5,65	2,54	2,22	71	70
2,00	6,28	3,14	2,00	88	90

(Note: Actual production rates will depend on the raw mix characteristics. Variations of ± 10% are likely.

8) Fuel Preparation:

The fuel preparation (a 50/50 mixture of coke breeze and SLV coal) consists of a double-roller crusher, fed by shovel, and a screen with 4.0 mm circular apertures. The device is suitable to crush the necessary fuel rate of approx 200 kg/h of coal.

9) Cement Mill and Bagging:

The dimensions of the clinker mill are identical to those of the raw mill; but the cement mill is operated as an air-swept mill with classifier.

Capacity 1,50 t/h
Gypsum added 5% of the clinker weight.

The fineness of the ground cement (2600-2800 Blaine) corresponds to the standard for ordinary Portland cment.

IV) FINDINGS AND COMMENTS

A) General

Table 8 presents a summary of the development history at Mohanlalganj.

The production of Portland cement is a chemo-physical process. In order to obtain good quality clinker it is absolutely necesary to maintain the raw material mix constant within the required limits from the chemical and the physical viewpoint; ie, the percentages of CaO, SiO_2, Al_2O_3 and Fe_2O_3, and thus the corresponding moduli have to be kept constant over long periods of operation.

The whole secret of making good quality clinker is to produce a standard, unvarying, composition of raw materials fed to the kiln. Ideally, each nodule fed to the kiln should contain its share of all of the raw materials in the right proportions. This underlines the importance of steady production at all stages of the process and good homogenization, in order to even out any natural variations in raw material composition.

The mix can of course also be changed deliberately, within the ranges required for the production of Portland cement clinker, and this is indeed sometimes necessary or desirable. Various plant settings, fuel rates, moisture additions, kiln operational settings will probably need to be changed, and because of the slow response time of the system sub-standard clinker can easily be formed in the time the plant is unbalanced.

It is obviously important that laboratory results are accurate and reflect clearly what is happening on the plant.

In conventional plant, much of this control over variations is achieved by automatic process control. Whilst many of these functions are manual in a mini cement factory, it is probably too much to expect that completely manual operations will give the evenness of production required in, say, feeding driers, and a certain minimum degree of mechanisation and process control is desirable, or even just appropriate instrumentation can help considerably.

In view of the above, the functional performance of the plan must be complemented by its reliability. Steady operation obviously cannot be achieved in a plant that continually breaks down.

It must also be emphasised that shaft kilns are inherently more sensitive to variations in raw meal composition than rotary kilns, on part because rotary kilns are quicker to respond to control action, and internal conditions can be assessed visually.

However, it was recognised from the outset of the project by Debour that variations in feed were going to be the rule under Indian conditions. Variable quality raw materials are typical of small deposits, where selective quarrying and stockpile blending cannot be practised. Also small plants in India are more liable to intermittent operation and erratic control.

All this led to Debour placing great emphasis on a high quality of homogenization and ability to compensate for raw meal changes through fuel additions and kiln control. Theoretically there were three options for fuel addition:

- Mixed feed firing, with fuel fed separately to the kiln. Whilst giving easy and rapid control of fuel input, it is not easy to guarantee even clinker burning.

- Fuel intergrinding. This gives good fuel mixing within nodules, but changes to fuel rate cannot be made speedily.

- Fuel intermixing, where fuel is added to the raw meal immediately before nodulising. This was adopted as the most appropriate solution, since even fuel distribution in the nodule would be combined with quick control of fuel ratio.

In addition, Debour recommended greater control of kiln operation through air control and grate discharge.

Table 8

	ORIGINAL PLANT	PROJECT RECOMMENDATIONS	IMPLEMENTATION	COMMENT & FUTURE RECOMMENDATIONS
1. Raw Material Crushing	12" x 6" jaw crusher 15 hp, 1.5 t/h followed by 18" 25 hp hammer mill set at - 3/8"	Equipment satisfactory	Crushing line relocated to feed end of drier.	No comment.
2. Drier	None	Ball mill capacity impaired due to moist feed. Hot air generator for Ball mill recommended. Calculation shows unacceptable air velocities. Separate rotary drier designed including balanced outlet feed hopper and apron feeder, heated by direct fired grate - type air heater built on to drier.	Space constraints let to reduction in diameter and increase in length. The air heater was positioned outside the building, connecting by insulated pipe line. Manual feeding, via bucket elevator for crushed material or belt conveyor for marl employed rather than apron feeder. Small roller crusher added to drier output. One sealing arrangement simplified.	Original recommendation for apron feeder to provide steady feed to drier correct, should have been implemented. With layout as it now exists a vibratory feeder and larger marl hopper perhaps a cheaper option.
3. Raw Meal Mill	Cube mixer (64 ft^3) followed by 3.7 m^3 Air swept ball mill with double cone classifier.	Replace air classifier by internal screen. Replace screw conveyor by air slide to homogeniser. Dispense with cube mixer. Insert double stage hammer mill before ball mill to increase milling capacity. Consider replacement of ball mill by tube mill.	The air classifier was taken out and an internal screen fitted. The air slide was installed and the cube mixer scrapped. One hammer mill was tried before the ball mill, to little effect.	Recommendations recognised problem of adequate milling. Implementation generally satisfactory, except that capacity of mill likely to be inadequate at full output, and separate pre-grinding of limestone would be beneficial. Drive motor undersized, and increase in ball charge not possible.
4. Homogenisation Section	450 ft^3 silo with internal re-circulating screw.	Install two 80 tonne pneumatic homogenisers. Replace bucket elevator to kiln top by pneumatic lift.	Installed.	Installed equipment satisfactory, but more operational attention needs to be given to batching of mixes to ensure uniform contents in each homogeniser. Simultaneous, mixed, discharge from both homogenisers could be considered to reduce this problem.
5. Fuel Addition	Coke breeze and other fuel added at batch weigher before ball mill.	Adopt fuel inter-mixing (white meal) process. Erect raw meal and coal silos and a water tank on the kiln top level. Feed via variable speed proportioning screw feeder to a paddle trough mixer. Add part of the nodulising water in the mixer	White meal process adopted. Silos changed from conical to cylindrical. Coal screw feeder replaced by belt feeder with intention of fitting belt weigher. Coke/coal crushing and screening plant installed to produce - 4 mm fuel. - 2 mm fuel considered. No water added. Improved mixer design considered.	Recommendation endorsed. Suggest grinding and screening fuel to -3 mm with 60% below 0.5 mm. Addition of approx ⅓ of nodulising water to paddle mixer should be implemented. Fuel proportioning as installed seems to be adequate.
6. Nodulisor + Kiln Feed	4.5 ft dia x 2 ft. rotating pan nodulisor	Install nodule surge silo and rotating distribution mechanism.	Rotary distributor installed.	Equipment satisfactory as installed. An attempt should be made to increase the proportion of nodules in 12-15 mm dia range, by decreasing angle of inclination. Better water control valve needed. The static plough fitted is not as satisfactory as the swinging ploughs used on large nodulisers.

Table 8

	ORIGINAL PLANT	PROJECT RECOMMENDATIONS	IMPLEMENTATION	COMMENT & FUTURE RECOMMENDATIONS
7. Kiln	1 m dia x 22 ft vertical shaft kiln. with conical grate. Mechanically operated triple gate discharge.	Increase kiln height by 1 m. Replace grate by half rotary cylindrical 4 - bar grate. Convert drive to variable speed hydraulic.. Incorporate means for air supply control. Install kiln instrumentation; flue gas temperature and pressure, air pressure and flow.	All recommendations adopted.	Kiln design and operation satisfactory, bearing in mind difficulties of running very small diameter shaft kilns. Kiln instrumentation should be refurbish Air leakage around grate should be stopped, otherwise air control will not be meaningful.
8. Cement Grinding Section	Similar to raw meal unit; ie, air swept mill with double cone classifier; cyclone collector and bag filter.	Classifier may be replaced by mechanical screen	Removal of classifier led to poor cement fineness and over heating of the gypsum; classifier reconnected.	Clinker mill operation satisfactory; again mill capacity barely sufficient. Drive motor undersized, and increase in ball charge not possible.
9. Dust Control Equipment and Mechanical Handling	Dust collectors on hammer mill, raw meal mill and clinker mill. Bucket elevators and screw conveyors throughout.	Four bag filters as follows: 1. Raw mill silo; rotary drier; homogeniser; 3 elevators. 2. Cement silo; elevators; clinker mill. 3. Raw meal mill; air slide; homogeniser silo. 4. Raw mill elevator to kiln; noduliser, homogeniser cyclone. Bucket elevators to be replaced by middle pressure conveyors.	Bag filters installed.	No comment.

To summarise, Debour's recommendations specifically relating to variable quality raw materials and built into the ATDA process were:

1) Drying of unconsolidated marl and kankars.

2) Close control of batch proportioning.

3) High quality pneumatic homogenization.

4) Fuel intermixing process.

5) Good control of kiln air and discharge rate.

All these aspects have been satisfactorily demonstrated at Mohanlalganj, with the possible exception of good batch proposition control, itself easily rectified.

B) <u>The Mohanlalganj Plant</u>

During the experts visit the following findings were registered:

1) Rotary drier:

The drier feed is very unsteady due to the fact that the feed hopper is too small and no proportioning feeder has been installed. The capacity of the drier itself is sufficient to dry the raw material necessary for a clinker production of 20 t/d down to a resiudal moisture of 0,5%. (1) *)

2) Bucket elevator:

Due to the variations in the drier feed, the drier discharge quantity also varies considerably. As the crusher and screw conveyor are adequately sized, peaks in the materials flow are forwarded to the bucket elevator and create frequent blockages of the elevator. Although the capacity of the bucket elevator itself is sufficient, it is very sensitive to peaks in the flow of material. (2)

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*) The figures in brackets are relating to the suggestions in Table 9.

3) Raw material storage silos:

The storage capacity of 75 m^3 of the 5 silos is sufficient. The problem is however the composition of the raw material mix. The proportioning system with a weighing scale of the weigh-beam type together with the hand operated flap feeders is by no means precise enough to guarantee a uniform mixture. Even with the best intentions the operators are not in the position to maintain a regular raw meal mix. (3)

4) Raw meal mill:

This mill is a very weak element in the whole plant. When limestone has to be added, the limestone particles are not sufficiently ground and this produces inhomogeneities in the raw meal. (4)

5) Homogenizing Silos:

Although the homogenizing system is big enough and the equipment installed is adequate, the chemical and physical compostion varies in the silo and even more when output is switched from one silo to the other. These variations in the raw meal mix are detrimental to the kiln operation. (5)

6) Nodulizer:

The dimensions of the nodulizer are adequate. The problems of the frequent variations in the nodule quality are ascribable to two main causes:

a) The frequent stoppages of the kiln, and consequently of the nodulizer, disturb the nodulizing bed.

b) The proportioning ability of the feeder-system is very poor and neither the raw meal nor the fuel are of constant fineness.

The fuel contains frequently grains up to 20 mm. (6)

7) Shaft Kiln:

The design of the shaft kiln is correct. The feeding chute and the oscillating roller discharge grate are operational. But the discharge grate is not air-tight, an uncontrolled quantity of air is leaking and therefore the combustion in the kiln is not fully controllable although an air-volume control is installed. (7)

Furthermore the opening angle of the conical portion of the kiln seems to be very small.

The fact that the clinker is stored for several weeks does not harm it, on the contrary, in storage any free lime becomes hydrated, which is an advantage for the cement.

Fuel rate:

It is recommended that coke breeze alone be used as the fuel. This will eliminate problems of uneven mixing of the SLV coal and coke breeze and give a more even heat input. Additionally crushing and screening will be simplified. The fuel rate calculation is now:

Kiln nominal capacity	=	20 t/d clinker
	=	833 kg/h clinker
For 1.58 t raw meal/t clinker	=	1,316 kg/h raw meal
Heat reqd 1,000 kcal/kg clinker	=	833,000 kcal/h
Using coke breeze 4,344 kcal/kg	=	192 kg/h coke breeze

$$\text{Fuel rate} = \frac{\text{Fuel}}{\text{Raw meal}} = \frac{192}{1316} = \underline{14.6\%}$$

8) Fuel Preparation:

Although adequate equipment has been installed, two problems have been identified:

a) The mixture of coal and coke is not homogeneous;

b) The screened fuel is frequently mixed again with the overflow of the screen. This is the reason why coarse grains are found in the fuel. (8)

9) Cement Mill and Bagging:

Although also the cement mill is too small, it can grind clinker and gypsum to a saleable Portland cement within the standard requirements.

Finished cement storage capacity (in silos) is adequate, particularly since there is a large capacity for clinker storage.

However the bagging equipment is rather poor and causes a high level of dust nuisance.

10) During the expert's visit drawings and operational decriptions have been assessed. It has been found that the documentation for the existing plant is complete and sufficient for the operation.

V) SUGGESTIONS

The dilemma of the situation is that the plant under present conditions cannot be expected to prove its reliability, on the other hand important investments, necessary to improve the operational conditions, are not possible due to the lack of funds. Therefore the suggestions presented in Table 9 have been selected in the light of the above mentioned situation, so they are limited to the very minimum in order to hopefully reach a continuous operation of at least 500 t/month of clinker, safely above the breakeven point.

If this operational condition can be maintained over a period of several months, the decision to build a new plant or to overhaul the existing plant can be made with more confidence.

The expert's opinion is that, under the actual conditions in UP State a thoroughly planned second generation plant would be the ideal approach.

Due to problems in the raw material supply during the monsoon period it seems best to stop the plant during the rainy season, install the suggested improvements and try again after the monsoon in a 4 weeks test to get the plant operating profitably.

19w

Table 9

Suggestions to Improve Operational Performance

(1) Rotary Drier:	In order to obtain a regular drier feed, the feed hopper should be increased in size and equipped with an electromagnetic vibratory feeder, the trough of which should either be coated with plastic or made from stainless steel in order to avoid sticking when the marl is too wet. A uniform drier feed will increase the efficiency of the drier as well.
(2) Bucket Elevator:	With the uniform drier feed, most probably also the bucket elevator problems can be overcome. If this is not the case a surge hopper with a proportioning screw-feeder should be located between the existing screw conveyor and the bucket elevator. This is possible by inclining the existing screw conveyor and installing the hopper of approx 500 l volume equipped with the feeder 100 mm dmr directly before the elevator inlet. Furthermore the tensioning device of the bucket elevator chain should be modified in such a way to keep the chain tensioned continuously either by fitting springs or by installing a tensioning weight.
(3) & (4) Raw Material Storage and Raw Mill:	In order to improve the uniformity of the raw meal mix the silo outlets should be equipped with screw-feeders; the weighing scale should be equipped with a dial-head (pendulum scale). On the dial the weight discharged from each silo should be indicated by travelling pointers. One silo should be reserved for preground limestone. That means that the raw mill has to be operated for a certain time with limestone alone and this preground limestone has to be stored in one of the raw materials silos. This limestone serves for correcting the lime standard, when composing the mixtures with the weighing scale. By this procedure the limestone is ground twice, so it will become fine enough to guarantee a homogeneous mixture.
(5), (6), (7) Kiln Operation:	It cannot be emphasised enough that the most important task is continuity and uniformity. It is absolutely necessary that the raw meal composition in the two homogenizing silos is identical. Furthermore the fuel should be fine enough. This relates not only to the maximum grain size which should not exceed 3 mm, but also to the grain size distribution, ie at least 60% of the fuel have to be below 0,5 mm. In order to facilitate the operation the expert recommends to use coke breeze alone for a certain period; and to grind and screen it to the conditions just mentioned. In order to improve the nodulizing process 1/3 of the total water should be added at the last third of the paddle mixer. The water addition in the noduler pan would be better controlled by installing a valve which allows finer control, preferably a needle valve. An attempt should be made to increase the proportion of nodules between 12 and 15 mm diameter; an increased retention time in the nodulizer may help this, achieved by reducing the inclination of the pan. In order to avoid jamming, please keep the real lime standard, ie the LSF corrected with the fuel-ash, slightly above 100. Furthermore continuous control of the kiln operation is desirable and avoid agglomerations by poking several times per shift. In order to obtain uniform burning conditions the discharge grate has to be tightened, ie it has to be equipped with a casing made from sheet metal; into which the hydraulic piston rod is introduced through a stuffing box. The laboratory should be equipped with an electrically operated test screen set, in order to become independent from the human influences.
(8) Fuel Preparation:	The present 4 mm screen should be replaced by a 3 mm screen. The fineness of the fuel should be checked frequently. Not only the maximum grain size is important, also the size distribution influences the burning conditions. Note: 60% below 0,5 mm. It has, of course, to be avoided that screened fuel is remixed with the overflow of the screen. A hopper underneath the screen can avoid remixing.

VI) OUTLOOK

A few statements at the outset:

1) It is possible to produce Portland cement from marl as the basic raw material, using VSK-Technology. The intermixing process is an adequate solution. Drying of the marl in a separate drier, as in the ATDA plant, is necessary, since moisture contents are too high for mill drying.

2) The operation of mini cement plants, using VSK technology can be desirable and economic under certain conditions as found in India and especially in UP State.

3) mini cement plants have to be designed in order to be reliable, ie the rules of sound engineering have to be respected.

4) It is beyond any doubt that, for each individual case a sound and reliable lay-out and design can be found. However it should be kept in mind that a mini cement factory is not a simple diminution of a large scale factory. The adoption of adequate design elements in equipment and lay-out is necessary.

The recommendation of the expert is:

To optimise a few mini cement plants for 30, 60, 100 and 200 t/d. Adapt a simplified computer programme to this kind of factory for raw meal batch design and to replace the very hard work of men by machines.

On the other hand labour should be kept busy for light work and surveillance.

In Table 10 supposed investment costs for different plant sizes are indicated based on information collected during the expert's visit to India.

Table 10

t/d	t/y	Investment Costs Rs
20	6000	6,720,000
30	9000	8,220,000
40	12000	9,900,000
50	15000	10,600,000
75	22500	13,000,000
100	30000	15,000,000

The expert recommend not to go below 30 t/d (9,000 t/y).

Of course economic conditions have to be computed for each individual case.

ANNEX 1

ATDA MINI-CEMENT PROJECT APPRAISAL MISSION

Terms of Reference

A. OBJECTIVES

1. Assess the mini-cement project against its original objectives.

2. Review the original project assumptions regarding the techno-economic viability of mini-cement technology in light of the current realities and foreseeable trends in the Indian cement sector.

3. Identify options and recommend a future course of action for both the existing Mohanlalganj Plant and the ATDA-developed mini-cement technology.

B. SCOPE OF WORK

1. Objective 1: Assess Achievements

1.1 Historical review of the project including key technical and financial inputs.

1.2 Describe the project's key technical and economic objectives.

1.3 Review the route adopted to meet these objectives, and the level of achievement. Describe the plant design and layout and in particular verify the level of implementation and success of the modifications recommended by Theo DeBour.

1.4 Assess the function and reliability of the elements of the plant set against required levels of performance. Identify remaining technical problems, define likely solutions, their cost and relative priority.

1.5 Summarise the economic performance of the project and the lessons learned to date.

1.6 Verify the quality and extent of plant documentation, including engineering drawings, flowsheets, diagrams, operating, quality control and maintenance procedures, indicating where changes and additions are likely to be necessary.

2. Objective 2: Validate Assumptions

2.1 Political and economic factors (eg, government regulations, industrial standards, pricing policy, taxation, concessional and/or commercial finance).

2.2 Market demand.

2.3 Market competition (mini-cement plants only).

2.4 Entrepreneurial/technical know-how requirements.

2.5 Development impact (eg, direct employment, income, access and price of cement).

2.6 Comparative advantages and disadvantages of ATDA mini-cement technology.

3. Objective 3: Future Actions

3.1.a Consider the options and recommend a course of action to disseminate the valuable aspects of the technology initially in the Indian cement sector and at a later stage to other developing countries. These options could include:

- licensing agreement with a responsible engineering firm;
- second generation commercial prototype plant in partnership with interested parties.

3.1.b Recommend revised plant layout and broad specifications on equipment and instrumentation.

3.2 In light of 3.1 above, consider the options (including the cost of further modifications and working capital) and recommend a course of action on the future of the Mohanlalganj Plant. These options could include:

- continued ATDA operation of the plant
- leasing arrangements with an interested party
- transfer to the UP State government
- orderly phase out of the plant

C. MISSION MEMBERS, TIMING, ACTIVITIES

1. Dates: April 9-19th

2. Team Members: Harro Taubmann, Consultant
Frank Almond, ITDG
Marshall Bear, ATI (mission coordinator)

3. Activities and Timing:

- ATDA Briefing (Chairman, Gen Sec, Director Projects) (1 day)
- Site Visit Mohanlalganj Plant (2 days)
- Site Visit to Another Mini-Cement Plant (1 day)
- Lucknow Discussions: Movers, EDA, UP Asbestos, USCST, UP State Government (3 days)
- Report Drafting (3 days)
- Report Presentation and Discussion with ATDA (1 day)

ANNEX 2

ANALYSIS OF MOHANLALGANJ CLINKER SAMPLES

1. The analysis was carried out by Dr Karl Czech of the Breisgauer Portland Zement Werke, Geisingen, W. Germany, to DIN standard 1164.

2. Summary Results

   2.1 Both samples represent well-burnt clinker, burnt under oxidising conditions, without the fuel residues often found in VSK clinkers due to burning under reducing conditions, agglomerate formation or when the fuel is too coarse.

   2.2 The analysis shows a high Al_2O_3 content and a relatively high free lime content, near to the permissible limit.

   The high Al_2O_3 content and the resulting C_3A formation will produce high heats of hydration, which means a quicker setting and a higher shrinkage coefficient.

   2.3 The silica and alumina moduli computed are below 2, giving a high liquid phase content, which would explain the jamming tendency.

3. Suggestions

   3.1 In order to overcome these problems the silica content in the raw meal mixture should be increased. This can be done by adding sand with a high SiO_2 content and low alkali content. Of course it must be taken into consideration that sand will reduce grindability and increases the difficulty of homogenisation. Instead of sand, the kankar content of the mix could be increased. (See in this context suggestions for different mix formulations).

   3.2 Another option, but most probably more difficult to implement, is to change the clay component. This way however is not suitable for the Mohanlalganj plant.

(signed) Dr Karl Czech 19 June 1985

ANALYSIS OF MOHANLALGANJ MINI-CEMENT PLANT CLINKER

	AGGLOMERATES		LOOSE CLINKER	
	Full Analysis	LOI-Free Basis	Full Analysis	LOI-Free Basis
LOI	0.89	-	0.70	-
Insoluble Residue	0.33	0.33	0.18	0.19
SiO_2	20.03	20.21	19.97	20.11
Al_2O_3	7½12	7.18	7.07	7.12
Fe_2O_3	3.68	3.71	13.66	3.69
MnO	nd	nd	nd	nd
CaO	63.64	64.21	64.39	64.84
MgO	2.91	2.94	2.96	2.98
K_2O	0.88	0.89	0.6[illegible]	0.63
Na_2O	0.37	0.37	0.34	0.34
SO_3	0.07	0.07	0.03	0.03
S	0.01	0.01	traces	traces
Cl	nd	nd	nd	nd
Balance	0.07	0.07	0.07	0.07
Total	100.00	100.00	100.00	100.00
$CaSO_4$	0.12	0.12	0.05	0.05
CaS	0.02	0.02	0.00	0.00
Free CaO	2.96	2.99	3.02	3.04
Residual CaO	60.61	61.16	61.35	61.78
Silica Modulus		1.85		1.86
Alumina Modulus		1.93		1.93
Free Lime Modulus		2.81		2.82
Lime Saturation Factor		95.06		96.60
C_3S		41.81		45.57
C_2S		26.40		23.28
C_3A		12.75		12.63
C_4AF		11.30		11.22
Liquid Phase (LEA)		34.10		33.61
(KUHL)		36.75		35.89

ANNEX 2 (Cont'd)

The analysis work was followed up by a computer-aided examination of the raw meal mix chemistry to explore the limits for utilisation of kankar and marl.

Four viable mixes were identified, representing the maximum and minimum marl and kankar percentages achievable.

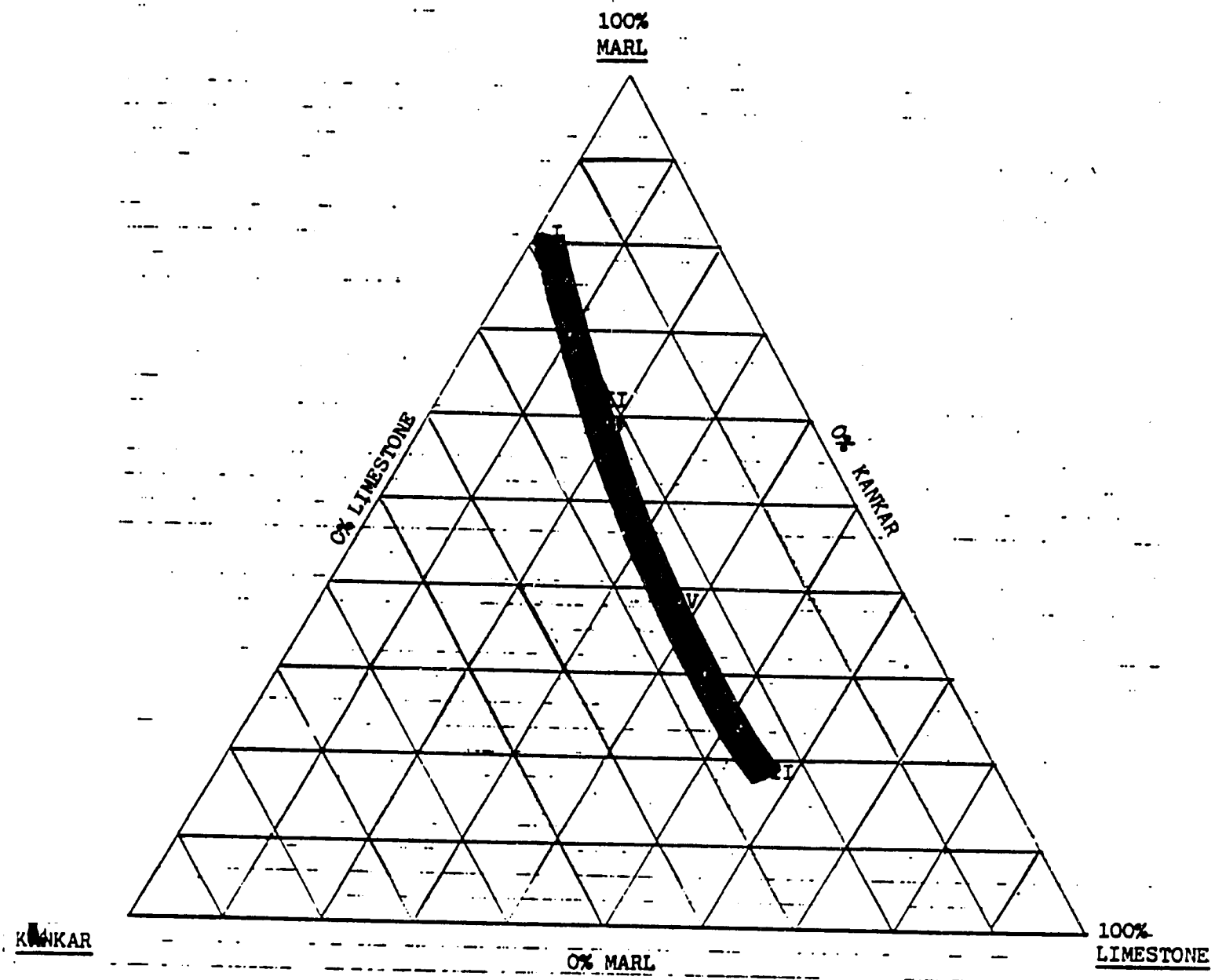
These mixes are plotted on the attached ternary diagram (Fig) and it is suggested that with more accurate data this could provide a useful graphical tool for mix planning.

It does not take account of ash compounds, and assumes average compositions for the three components. More accurate mix chemistry could be handled on a microcomputer.

	MIX I	MIX II	MIX III	MIX IV
Marl	80.3	18.5	58.9	38.3
Limestone	0.94	54.9	19.7	33.6
Kankar	18.8	26.5	21.5	24.1
LSF	97	97	97	97
SiM	2.4	2.7	2.5	2.6
AlM	1.95	1.93	1.94	1.94
Liquid Phase	30.9	24.3	28.6	26.4

It would seem that outside the range of silica modulus 2.4-2.7 a viable mix is not possible.

On the above evidence, a mix approximating to Mix III would seem best for Mohanlalganj; a medium liquid phase fraction and 21.5% kankar utilisation.



OPERATING RANGE FOR MARL/KANKAR/LIMESTONE BLENDS