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APPROPRIATE TECHNOLOGY FOR THE PRODUCTION OF CEMENT AND BUILDING MATERIALS

PROJECT PROPOSAL AND FEASIBILITY DATA FOR A 25 TON/DAY MINI-CEMENT PLANT,

Background Paper

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PROJECT PROPOSAL AND FEASIBILITY DATA FOR
A 25 TON/DAY MINI-CEMENT PLANT

by

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CHAPTER I

Binding of bonding or cementing material for building and structural purposes is a basic necessity not only for developing countries but also for affluent nations. Three kinds of materials have been developed over the ages:

(1) Lime mortar,

(2) Natural cement, hydraulic cement i.e. higher quality of lime mortar,

(3) Portland cement.

At present Portland cement is more or less exclusively used in building activities. The use of other kinds is very marginal.

The basic raw material required for all the three classes of cementing material is **lime** (CaO). It occurs as calcium carbonate widely in nature in various types of minerals mostly limestone. But many other varieties like coral nodules, coral sand, seashells, marl, cement rock, kankar in India, etc. are also available.

The lime mortar is manufactured by burning the calcium containing mineral separately and then mixing it with burnt clay, sand, coal ash, etc., in a watery solution and then it is directly used. Many of the calcium containing minerals like kankar contains both lime and clay material and are burnt as such, grinded and then used. This kind of mortar has got low strength of 1/3rd of ortland cement and it takes 3-6 months to set properly.

The second class of binding material is manufactured by mixing and grinding together the calcium material and the clay material. This mixture is burnt in a kiln to a slightly higher temperature than in case of lime mortar. The strength of this material is about one half that of portland cement and the setting time is about double.

The Portland cement is a further extension and intensification of the above technology. The ingredients are mixed in a definite and controlled proportions and then grinded to a much finer stage, requiring sophisticated equipment. The burning is carried to a very high temperature of 1450° C which make the kiln intricate and costly machinery both in the capital side and the operational side. The resultant burnt material called 'Clinker' is then subjected to very fine grinding with addition of gypsum. This product has got very high strength, quick setting time and meets all the standards and structural needs of the present-day building activity. It has got the further advantage that it can be diluted to about six times by adding sand. The resultant mixture is economic to use and still attains higher strength than lime mortar and even compares favourable with the natural cement. The cost of the diluted mixture is generally less than the other two kinds of mortar except in special locations and sometimes due to market fluctuations and to short supply of portland cement.

A large number of attempts have been made to improve the quality of the mortar of the first two types. Pozzolana cement, slag cement and now the rice-husk cement have been advocated . The first two categories are only a sort of dilution of the portland cement clinker with special kind of burnt clay or slegs. This only increases the volume of the cement production and gives a class of material which again does not replace the portland cement but acts as a substitute for a part of the building job like plastering, building walls, etc. These products are only as an auxiliary production of portland cement plants. Rice-husk cement again does not come up to the structural quality of portland cement. Its economics are possible only where low cost raw material, i.e. calcium waste is available from some of the industries like carbonation sugar along with rice husk. The investment on economic plant may be considerably higher than for lime mortar. The equipment also will have to be mechanized. For standardizing the product the design of the equipment will have to be much more complicated. Even then the setting time is about 60-66% that of portland cement. The cost of prepared mortar is also high as oompared to 1:4 to 1:6 of portland cement and sand mixture.

In short, the available type of lime mortar or natural cement do not oome up to the requirement of the present-day building requirements and any improvements carried out loses the advantage of low-oost, simplioity of operation and capability of being installed in remote rural areas and even then the produot will not have preference, if portland cement is readily available.

It appears, therefore, there is hardly any choice left for planners except to opt out in a big way for portland cement. The question is whether to do it in large scale plants located near the lime stone deposits involving heavy transport cost to the consumer market, requiring very high capital and taking a lot of time for gestation for coming to the required production level or can this be done in small dispersed units near consuming markets by utilizing local deposits of calcarious raw materials with lower capital investment, having much smaller gestation period with a capability of building a quick machinery manufacture complex and make portland cement available in less time at a lower cost by cutting down transport and packaging charges. The other advantage would be creating a sizeable job employment in rural areas and boosting up rural economy by increasing capital formation, by setting up decentralized mini cement plants.

CHAPTER II

Technology of Portland Cement

Portland cement was first discovered in 1824 by Joseph Aspdin, in the shape of accidentally over-fired material produced in intermittent vertical shaft kiln used for manufacturing natural cement. This over-fired material was found to set remarkably quickly and to have higher strength than the natural cement.

The manufacture of portland cement increased slowly and gradually and replaced other type of cement almost entirely.

The portland cement process consists of:

(1) Mixing of raw material under rigid analytical control,

(2) fine grinding of the mix (either in wet or dry condition),

(3) firing (calcining) the mix to a temperature of 1400-1450° C,

(4) fine grinding of the fired clinker with addition of a small amount of gypsum.

Out of these processes the most important is the proper firing of the mix to the right temperature under the right conditions. The kiln has therefore been called "the heart of the cement industry" and determines the economics and scale of production and quality of the product.

Until the turn of the century the kilns used were more or less like the lime kilns of today having a wider lower portion and fireboxes all around the circumference to give additional heat to obtain the right temperature. They worked on a batch system, that is the kiln was filled, fired, cooled, discharged and again filled. Production capacity was therefore low, the quality of the product varied from kiln to kiln and the process was rather too labour intensive for present day labour costs.

An important new development took place in the form of the rotary kiln in 1900. This kiln is a long slowly rotating horizontal shaft, inclined at a small angle. The material is injected from one end in the form of either wet slurry or dry pellets (nodules) and the fuel (pulverized coal or oil) is injected as a jet from the other end.

The main difference between the vertical shaft and rotary types of kiln is the principle of heat transfer utilised. In the vertical shaft kiln heat transfer by conduction plays a more important role than radiation, whereas in the rotary kiln radiation is more important than conduction. Heat transfer by conduction can be efficient in a relatively small space and beyond a certain size heat transfer efficiency drops due to high radiation losses. On the other hand heat transfer by radiation is progressively more efficient in larger spaces due to lower heat losses. This basic fact led to the development of larger and larger rotary kilns. The vertical shaft kiln can be feasible with a capacity of as low as 1 ton per day, and has maximum efficient capacity of 200 t/d

Whereas the minimum efficient capacity of the rotary kiln was judged to be 300 t/d, but in India at present there is a move to have rotary-shaft kilns installed of 100 t/d. It appears that due to high cost and other auxiliary equipment such small complex may not prove economically viable because at one time even 300 tons rotary-shaft kiln installation has to be given up.

Nowadays, capacities of 3000 t/d and more are preferred, as explained in the following extract (from a report of the Readymix Cement Engineering Co.): "Reason for the trend to large scale plants. The development of the process engineering of clinker burning has always and especially in Europe, been very much affected by the energy costs. It has been found in very recent times that clinker can be produced more economically in large rotary kiln installations."

In accordance with this finding, kiln units with a daily output of 3000 tons and more were then preferred in the cement industry.

Based on theoretical considerations, the following advantages were ascribed to these large-scale plants:

(1) Heat saving because of lower radiation heat losses in the kiln area.

(2) Lower capital investment per ton produced.

(3) Saving in personnel costs.

(4) A general reduction in all other running costs such as spare parts, lubrication, maintenance.

This development was naturally followed up in the total cement machinery and ancillary equipment industries and especially in the technical sections of the milling of raw meal and cement.

By the nature of things no savings can be expected on the energy side with these machines. There remain, therefore, only lower specific investment sums, lower personnel costs and a reduction of the usual operating costs."

However, in practice these very large scale plants have not produced the economic advantages expected, as is explained in the following extract (from the same Readymix report):

"Experiences with large-scale plants. After starting operation with the conventional large scale plants mentioned above, it was found that the expected economical advantages were obtained only in part, i.e.:

1. The fuel savings between a 1000 and a 3000 t/d kiln (1000 t/d with cross-current grate cooler, 3000 t/d with satellite cooler) should be between 166 kJ and 250 kJ/Kg. of clinker and thus no more than US $ 0.30/t, referred to 1973.

2. The specific investment costs have not dropped substantially by the installation of large units. It is extremely difficult to make an accurate statement since the various information provided is not based on precisely defined investment amounts.

3. Whereas there is a saving on skilled production workers, greater expenditure is necessary on servicing personnel. The servicing personnel must also be more highly skilled than is necessary for smaller plants.

4. As regards operating costs, experience must first be gained in the coming years. So far, it has been found that here too one must expect a smaller economical success than expected. At a rate of 0.6 to 0.9 kg/t of clinker, the lining wear is probably greater than that of the smaller rotary kilns.

In addition, there is only a limited amount of competition among machine manufacture because there are only a few companies capable of producing large-scale plants of the kind mentioned above. This has an adverse effect on the investment costs in building a plant of this kind.

In this context, it should also be mentioned that the anti-pollution laws are continually tightening up and this often results in a very tedious process of obtaining approval especially where the construction of large cement works in industrial densely populated areas is concerned. Furthermore, a great deal of capital is tied up on such projects even during the lengthy planning, approval and construction period. Finally, mention should also be made of the fact that of necessity much capital is tied up in large raw material stocks. To match production to a small market requirement involved considerable costs in the case of large-scale plants."

Similar trends regarding large scale cement plant are also coming up to surface in India. With the cost of plants rising cement planners find that only large size plants are becoming economically viable. However, with total financial outlay being large with long gestation period required new plants have not been coming up at the rate required to fill up the gap of the shortage as is indicated by the following production of 5 years plan 1978 - 83:

Cement production in India

1977 - 78		1982 - 83	
Installed capacity million t	Actual production million t	Installed capacity million t	Estimated production million t
21.87	19.2	35	30

The techno-economic feasibility of setting up mini-cement plants, particularly in locations, otherwise removed from production centres of cement, is also under consideration.

"On the basis of the above knowledge", the German report further quotes, "it can be said that a cement mini plant will be able to match the future requirements only if it includes a burning process of a kind which exhibits the economical features of the large-scale plants." For which purpose the following requirements have been identified:

(1) The environmental oompatability, the operating oosts, the investment costs, and the operational reliability must be oompetitive with those of a large rotary kiln.

(2) The unit must permit any fuel to be used and must therefore be flame-heated.

(3) It must be easy to handle to avoid highly qualified technicians to have to be on hand for small production runs.

(4) Quick starting and stopping times of the plant should provide additional advantages compared with the large rotary kiln, for example shutting down the plant at weekends, etc. This possibility represents an improvement in the working conditions for the employees also in the sense of humanizing the working environment.

The vertical shaft kiln meets all the above requirements except No. 2. No doubt, use of oil as fuel gives a easier temperature control leading to quality production but the fuel cost becomes higher and adverse.

The vertical shaft kiln went almost completely out of use by the 1930's. However, certain limitations and problems of the large scale rotary kiln plants led to a revival of interest in improving the vertical shaft kiln. Now designs were developed with continuous as opposed to batch operation; this reduced fuel consumption to a lower level than in rotary kilns and improved the oonsistency and quality of cement to the same standard as that in rotary kilns. By 1940 new designs of vertical shaft kiln found acceptance and were used in the cement industry. During the second World War the vertical shaft kiln was the backbone of the German cement industry, and after the war the technology spread to other countries.

The mini cement plant have been attracting attention by international agencies and by industrial economists concerned with development. Mr. Jon Sigurdson has quoted as follows:

"The global production of cement was 700 million tons in 1974 most of which was produced in rotary kilns. However, approximately 5%

from vertical, usually relatively small kilns most of which are located in China. The World Cement Directory gives 72 locations in 17 countries China not included, which together have more than 200 kilns in operations. See Appendix III. This dominant majority of the vertical kilns outside China are found in France, Germany, Italy, Spain and Yugoslavia."

The most spectacular use of the vertical shaft kiln has been made by China, where small scale vertical shaft kiln plants now produce about 19 million tons of cement anually, 50% of China's total annual production of 38 million tons. The number of small scale vertical shaft plants in China has grown rapidly from 200 in 1965 to 2800 in 1972 (source: Jon Sigurdson, various papers). The most striking features of this development is that the average production capacity of these small plants has been reduced from about 75 t/d to about 25 t/d. This has made it possible to disperse production throughout the rural areas and to utilise small local reserves of calcareous materials too small to support a large scale plant. Another important aspect of the Chinese development is that these small vertical shaft kilns are being used to produce lime, lime-surkhi and pozzolana cement as well as high quality portland cement.

In Germany, cement type vertical shaft kilns are also extensively used to produce lime and to calcine dolomite and other such minerals when necessary. The rotary kiln cannot be adapted to such multi-purpose use. Recently UNIDO sponsored a world wide study of vertical shaft kiln technology and came to the general conclusion that the increasing transport costs definitely have an impact on the cement price and some Least Developed Countries and Regions might be able to establish small scale cement plants producing good quality cement at prices competitive to long distance transported cement.

The main advantages of modern small scale vertical shaft kiln plants can be summarised as follows:

(1) Small plants can utilise small reserves of oalcareous materials that are widely scattered throughout many oountries and cannot be utilised by large plants.

(2) Small plants allow dispersal of production in rural areas so creating a better balance of regional development.

(3) Small plants create more employment per unit of investment an important consideration in developing countries.

(4) Lower transport and distributive costs due to proximity of consuming market and possibility of selling unpacked cement to local consumers. This is important as packing, transport and distribution account for about 25% of the cost to the consumer of cement produced by large rotary plants (in India).

(5) Simpler machinery of small plants allows quicker development of machinery manufacturing capacity due to possibility of using less sophisticated, less capital intensive workshops.

(6) Simpler machinery allows quicker spread of know-how among less skilled personnel.

(7) Quicker installation and running-in of new plants (1 year as against 5 years for a rotary plant in India) which improves cash-flow and makes quick build-up and production possible (as in China).

(8) Capability of producing a variety of different cementitious products to suit local needs.

(9) Greater flexibility in rate of production to meet fluctuating demand, due to lower costs of shutting down and starting up and possibility of operating several kilns in parallel.

(10) Lower capital investment per ton annual cement production (about 50% of that required in large rotary kiln plants). This is a very important factor as capital costs account for about 50% of the cost of productions in a large rotary plant.

(11) Lower fuel cost per ton of cement produced,

(12) Electric power consumption not greater than in larger rotary plants.

(13) Lower consumption of grinding media and kiln.

(14) Lower spares and maintenance costs than in large scale rotary plants, due to simpler machinery and smaller inventory or spare parts.

CHAPTER III

Details of the development work done in India

With the successful utilisation of vertical-shaft kiln technology for cement production in various countreis, specially in Germany and China, why this technology has yet not been implemented in India? This idea was taken up as early as 1949 and quite substantial development work has been carried out but yet no commercial production has started. Jon Sigurdson, while reviewing the development of vertical shaft kiln in various countries makes a cryptic observation:

> "India has achieved a technical competence in the design of mini cement plants that matches or surpasses China - at least under laboratory conditions."

The reasons could be summarised as follows:

(1) In European countries and specially in Germany the vertical shaft kiln technology has been developed on the basis of kiln design of daily capacity of 180 to 200 tons. 4 - 6 kilns of the above capacity are installed in one unit. The unit thus becomes not a mini-cement plant but large scale cement plant, with the only difference that in place of a rotary kiln a battalion of vertical shaft kilns are used. This model and design of kiln could not serve the purpose for decentralized mini-cement technology - required under Indian conditions.

(2) The vertical-shaft kiln used in China has a daily capacity of 25 - 30 tons which is also the requirement in India, but the quality of cement produced in China by those kilns is not portland cement and cannot meet the Indian standard specifications. In China the development of technology, its operation and consumption of its products are all controlled by, and the responsibility of commune and other government bodies. They can exercise control where low quality cement should be used and where high quality cement should be used. The production cost

factor is also not taken into account. Therefore, the chinese have been able to operate small scale cement plant even when they do not produce cement upto the full portland cement specification and are probably not as efficient in other respects.

But conditions in India are different. Government agencies are disinclined to extend any technique about which there is slightest doubt. The entrepreneur and other business organisations not being involved in the R and D process, do not have sufficient confidence in research agencies to take new technologies without some kind of guarantee and technical assistance which has never been offered in the case of mini-cement plants. Furthermore, the consumer is not prepared to accept the low quality product, even on a lower prioe, when portland cement is available.

If the mini-cement technology has to take root in India and provide the various advantages envisaged it has to fulfill the following conditions:

(1) The vertical shaft kiln design should be between a capacity of 25 to 30 t/d and possibly not higher than 50 t/d.

(2) The technology should be so developed that a unit can operate on the basis of one vertical shaft kiln of daily capacity of 25 to 30 tons to produce portland cement meeting Indian standard specifications.

(3) To achieve the eoonomic viability and to meet this economy of scales of large scale production, besides other factors like lower transport and packing cost due to location near consumer market and direkt sale to consumer; it is essential that oapital oost on the unit should be not more than 50% of the unit of large scale production per ton of annual production.

(4) To enable the location near the consumable market, these plants hould utilise looal raw materials as far as possible. Any shortooming of the local raw material should be balanoed by lime-stone, whioh may be transported from reasonable distance. In case the plant depends on lime-stone only as source of raw material then the plant has to be located at long distanoe from the consumption market and their eoonomic viability will be very difficult to prove and the advantage of dispersal resulted in creation rural employment and

improve the rural economic conditions will be lost.

The thrust in the research programme, except at Mohanlalganj project of planning research and action institute, for developing mini-cement technology by Indian technologists was for evolving only the kiln design of 25 t/d capacity, based on the use of lime stone as raw material without giving attention to the other machinery design with lowest cost factor.

The following is the brief description of these efforts:

(1) In 1948 Shri Khandelkhar started experimental trials at the Sanghli works of the Deccan Cement Co. on the production of cement on a small scale. He continued this work up to 1967 and ended with the development of not a conventional vertical shaft kiln but a batch type of kiln using part oil and part coal as fuel. The raw material used was lime-stone. However, the cement produced did not meet portland cement specifications, and was equivalent to natural cement. This product was marketed as 'Segoli' but did not find acceptance and the project was dropped.

(2) The Defence Department decided to initiate design of a small scale cement plant, to reduce the cost of transporting cement to remote and inaccessible areas. A team was formed which designed a 25 - 30 t/d vertical-shaft kiln. A proto-type was erected at Ordinance Factory, Moradnagar in 1962, it was tested and reported to be capable of producing portland cement. No other machinery (for grinding, etc.) was designed or erected and the Defence Department lost interest in the project.

The kiln was offered to various State Governments to build a pilot plant complete in all respects. The offer was accepted by the Tamil Nadu State Government. A pilot plant of 25 t/d capacity was set up near a large cement factory and obtained lime-stone and other raw material from their quarries. Major Ramachandran, the mechanical engineer in the Defence Department design team, was put in charge of the development of this pilot plant. The plant was completed in 1966. The machinery was selected from those already being manufactured by standard firms. The capacity of various machineries did not match and the investment cost was more or less equivalent to large scale cement plants.

The operational trials revealed many handicaps, particularly in the kiln. The kiln did not achieve a high enough temperature to produce portland cement. The plant was transferred to the Tamil Nadu Development Corporation after some rectification, who did not succeed in operating it on a commercial basis. Later on, the plant was handed over to the Indian Cement Research Institute (C.R.I.). C.R. I. has made certain alterations conducted pilot trials and published various papers on the design of the kiln, but no data of its performace have been given out. However, the plant has not as yet been put into commercial operation. The C.R.I. claims that it has design of vertical shaft kilns of 1 - 100 tons capacity but recommends setting up of 50 tons plant at the site of lime-stone deposits with a capital cost of US $ 75,- to $ 88,- per ton of annual production as against the investment of US $ 94,- for large scale plants. No attempt to design and develop other necessary machines has been made.

(3) Dr. M.S. Iyenger, associated with the Defence Department design team, on taking over directorship of the Jorhat Regional Research Laboratory, Assam, continued R and D work on vertical-shaft kilns in their laboratories. Besides working out certain modifications to the original design, he claims to have developed designs for still smaller vertical-shaft kilns with capacities down to 1 t/d, which were tested only on a laboratory scale with lime-stone as raw material. No pilot plant was established to test the economic viability of these designs but the patents were handed over to the National Research Development Corporation for exploitation, which so far had not been able to get any mini plant set up in the country.

(4) The Planning Research and Action Institute, Lucknov set up by U.P. State Government to carry out pilot experimentation and action research on community development programmes has a section on rural industries. This section investigated the possibility of pilot experimentation on small scale cement plant in 1958, but due to a substantial knowledge gap did not proceed any further. But in 1965 after receiving the design of the vertical shaft kiln developed by the Defence Department and studying the Dalmiapuram pilot plant, decided to design, build and operate a pilot plant, with the following objectives: (The entire work was carried out by the author of this case study)

i) The vertical shaft kiln design should have a capacity of 25 - 30 t/d

ii) The raw material to be utilised should be Kankar a local calcarious deposit scattered very widely in Northern India. To balance the composition another local raw material called 'Marl' should be utilised. In place where 'Marl' is not available, lime stone should be used to balance the deficiency of Kankar.

iii) The various machinery for grinding, pulverisation, etc. should be so selected or designed as to reduce the capital cost to 50% that required for producing per tonne of cement by large scale plants.

The project was initiated in 1967 at Mohanlalganj, 13 miles from Lucknow - a big summer market. Withing about 40 miles radius enough Kankar and Marl deposits, a raw material equivalent to lime stone are located which have been investigated by Geological Survey of India. The same design of vertical-shaft kilns of 25 - 30 tons capacity as developed by the Defence team was adopted. The design of the other machineries was prepared with the help of Shri V. Poddar of M/S Sahu Jain of Dalmianagar and Shri Kothari of Sugar and General Engineering Co., Jagadhri. The machinery was fabricated in small and medium workshops. The plant erection was finished by 1969, the trial done in 1970 gave a lot of gaps and teething trouble with auxiliary machines. The remodeling work of the machine took about a year. But the hardest blow was that the kiln when put in operation did not produce more than 25% well burnt clinker. The complete kiln design was then carefully reviewed and substantial changes were made. In 1971-72, after remodeling, the kiln was put in operation. It produced good portland cement which met all other requirements of I.S.S. except expansion ratio. This problem was examined and was found that the free lime in the clinker is higher and varies between 3% and 5%. The reason for free lime was investigated by a number of Indian teohnologists who were invited to advise in solving this problem including a cement consultants firm of international repure having foreign collaboration , but the problem could not be overcome. The other difficulty was that the kiln condition used to vary off and on giving poor quality cement for some time.

During the trials approximately 1,000 tons of cement were produced out of which 600 tons of cement were marketed as portland cement and found ready acceptance. The U.P. State PWD used this cement in construction work and found it acceptable except that its expansion ratio was on the high side making its use for structural and load bearing purposes of doubtful safety. The U.P. Governme t decided to transfer Mohanlalganj plant to U.P. State Government Corporation for further development. But the work was not followed and the plant is lying idle.

The Intermediate Technology Development Group (I.T.D.G.), London, got interested in the efforts made in Mohanlalganj for developing appropriate technology for mini-cement. They sent Mr. Robert Bruce, an associate of I.T.D.G. to India to make a detailed report on Mohanlalganj Cement plant.

On the basis of economic and production data from the Mohanlalganj plant and data supplied by the Cement Corporation of India on the 1200 ton rotary kiln plants currently being installed in India, Mr. Robert Bruce concluded that a 25 ton vertical shaft plant could successfully compete with the large plants, provided they consistently produce full standard Portland cement. To achieve this it will be necessary to seek expert technical advice, probably in West Germany, on the operating techniques necessary to achieve greater consistency of product quality. These remaining technical problems should be fairly simple for an experienced cement expert to resolve.

He further recommended that to bring about wide extension of this technology in India it will be necessary for a non-government agency to erect and operate a new 25 t/d plant in partnership with an entrepreneur or other business or autonomous development agency. This plant should be based on the Mohanlalganj designs which seems to be the most advanced available, but an advanced technical expertise should be obtained (a) to remove the present discrepancy and to draw up the full plant specification, redesigning where necessary and (b) to work in India for the first year of the plant's operation.

These two steps should remove any remaining doubts about the feasibility of this technology and create the required atmosphere of confidence to attract entrepreneurs to invest in it.

ITDG arranged in May 1977, for Garg to visit Kenya and Europe, with complete plans and specifications of the Mohanlalganj pilot plant so that these could be examined by German experts and an independent opinion obtained.

Shri M.K. Garg visited the following vertical shaft kiln working in Kenya and Germany and also have discussion with some German Organisations who were in a position to give consultation advice:

1. Bomburi Cement Plant, Mombasa, Kenya.
2. Erik Bomke, Beckum, Federal Republic of Germany (a vertical-shaft) technologist recommended in the UNIDO report).
3. JWI Cement Works, Ilse, Padborn, Federal Republic of Germany.
4. Annelisse Cement Works, Paderborn, Federal Republic of Germany.
5. Wittokinde Cement Works, Erwittee, Federal Republic of Germany.
6. Readymix Cement Engineering Co., Beokum, Federal Republic of Germany.
7. GOPA Consultants, Bad Homburg, Federal Republic of Germany.
8. German Ministry of Economic Co-operation and their executive wing, GTZ, in Bonn, Federal Republic of Germany.
9. Teohnology Transfer and Co-ordination Centre, Stuttgart (also the Government of the Federal Republic of Germany).

Technical Report of Mohanlalganj Cement Plant

M.K. Gang reported the following from his teohnioal disoussions:

The high 'free' lime oontent of the cement produced at Mohanlalganj leading to the high expansion ratio, was caused largely by a failure to reach and maintain the full temperature (1400 - 1450°C) in the kiln. Various simple proocedures should be adopted to rectify this:

1. The 'mixed meal' rather than inter-grinding process should be used.

2. The forced air flow in the Mohanlalganj plant was 1.5 times what it should be. This needs to be amended and a control system to vary airflow that oan be easily operated by the kiln operator should be installed.

3. The feeding of nodules should be controlled as per the flue gas temperature at the base of the chimney, which should not be allowed to rise above 80°C and should be kept around 60°C - the average in the Mohanlalganj plant was around 150°C.

4. The flue gas temperature can further be controlled by installing infinitely variable gearing for the grate so that the rate of clinker discharge can also be controlled easily and quickly by the kiln operator so as to keep the burning zone stable at the correct level.

5. It is necessary to control carefully the quantities of the constituents in the raw mix, particularly the heat input. For this purpose, the heat content of the fuel will have to be tested and adjustment made to quantities if necessary, from time to time, which was not done in the Mohanlalganj plant. Mr. E. Bomke who studied the processing and data of Mohanlalganj plant was able to state:

i) work done so far was on the right lines;

ii) he was prepared to undertake a detailed examination of the data and produce a revised set of drawings and specifications incorporating the modifications referred to above, and

iii) thereafter, he would be prepared to act as consultant during the installation and initial operation of a new plant.

These opinions were re-affirmed in London at a subsequent meeting between ITDG staff, Mr. Garg and the German experts during which details for future co-operation between the parties concerned were worked out.

The project was decided to be carried out in two phases:

<u>Phase I</u>	Examination of existing data and preparation of drawings and specifications by West German experts.
<u>Phase II</u>	Purchase/erection of land buildings and plant; testing and demonstration under operational conditions by the ATDA under the advice and guidance of West German experts.

The total capital requirement is represented by:

US $ 78,400	to commission West German experts to examine existing data, prepare a new set of drawings and specifications and provide advice and guidance to ATDA in erecting and commissioning the plant.

US $ 163,660	representing 50% of the oapital cost of the pruchase/ erection of land building and machinery required for the plant; the balance of the funds will be provided by Indian interests.
US $ 54,880	for overall control and management of the project including the initial costs of operating the plant for one year while testing, demonstrating and documenting its viability.
US $ 296,940 =	TOTAL

During his visit to the Federal Republic of Germany, Shri Garg had discussions with the Federal Ministry of Economic Co-operation and their Executive Wing GTZ in Bonn. They agreed that in case the Indian Government forward the request of ATDA for German advisory services they will meet from their own funds the cost of US $ 78,400 of the first phase and provide the necessary facility for examining, drawing design, work out modification, if needed, and provide operational help to assist in the erection and operation of the plant for the first year.

The request to obtain these funding was submitted to the Indian government by ATDA in August 1977 and after very extensi e examination of various issues, the Government has finally cleared the request and sent it to the German government in May 1978. The action is now awaited from German side. In the meanwhile for meeting 50% capital, ITDG approached various agencies.

As a result Appropriate Technology International of U.S.A. has agreed to provide US $ 163,660 to meet 50% of the cost of the pilot plant amount on receipt of the detailed project report indicating location and giving raw material. The report will be prepared in collaboration with German experts.

The capital cost and operational details are given in Appendix I. A comparative cost of production between large and small scale cement plant is given in Appendix II.

APPENDIX - I

Capital Cost and Operational Details of 25 ton Mini Cement Technology Based on Vertical Shaft Kiln.

1. Capital investment	US $	
i. Land and buildings		
Land 5 acres *) at US $ 1,250	6,250	
Buildings 10,000 sq.ft **) at US $ 3.75	37,500	
	43,750	43,750
ii. Machinery (all motors, etc. included)		
1. Jaw crusher (capacity 4 tph)	1,875	
2. Hammer mill (30" ***) size)	2,500	
3. Weighing equipment (raw mix)	2,500	
4. Mixer - concrete type (capacity 2½ t/h)	2,500	
5. Ball mill (raw mix) air conveying gravity separator capacity 2 t/h	43,750	
6. Homogenizer continuous circulation fluidiser	3,750	
7. Noduliser and silo	5,000	
8. Vertical shaft kiln and Rootes blower, instrument panel, variable speed grate, drive, discharge gates, staging, etc.	75,000	
9. Ball mill (cement)	43,750	
10. Elevators and conveyors	12,500	
11. Raw materials silos	6,250	
12. Cement silos	6,250	
13. Installation and erection	15,625	
14. Laboratory building with test equipment	12,500	
15. Miscellaneous	35,000	
	268,750	268,750
iii) Working capital		62,500
Total in M.		375,000

*) 1 acre = 0.4047 ha **) 1 sq.ft. = 0.0929 m^2 ***) 30" = 762 mm

2. Gross Income

i. Production (per year)
capcity 30 tons per day
actual production 25 t/d
320 days per year — 8,000 t

ii. Sale price
(1977) market price of Portland cement, transported and sold in 50 kg bags — US $ 56 per ton

in 50 kg bags	US $ 56 per ton
less taxes	18
Net price	US $ 38 per ton

The 25 ton plant will market cement straight from the silo (unbagged) and customers will supply their own transport, The margin allowed by the government for packing and transport is US $ 10 per ton. The price net to the 25 ton plant is, therefore, expected to be about US $ 27.50 per ton.

Gross income expected per year:

8000 tons at US $ 27.50 — US $ 220.000

3. Running costs

Running costs are estimated on the basis of 1977 prices and quantities from data of the Mohanlalganj plant. Costs are given in US $ per ton of cement.

i. Raw materials

Limestone	0.90 tons at $ 6	$ 5
Kankar	0.65 tons at $ 2	$ 1
Correctives	0.05 tons at $ 3	$ 0.15
Gypsum	0.05 tons at $15	$ 0.75
		$ 6.90

ii. Fuel

The Mohanlalganj plant regularly achieved a fuel consumption of 0.18 tons per ton of cement - the fuel is mainly coke breeze with some coal added. The heat input averaged 3962 kJ/kg of clinker in the 175 t/d vertical shaft kilns used in Germany and 4795 kJ/kg clinker in the 1,200 ton wet process rotary kilns of the Cement Corporation of India.

Coke breeze	0.15 tons at $ 9.38	$ 1.40
coal	0.03 tons at $18.75	$ 0.56
		$ 1.96

iii. Electric power

The Mohanlalganj plant consumed an average of 150 kwh/t cement as compared to 140 kwh/t in Cement Corporation of India, 1,200 t rotary plants.

Power 150 kwh at US $ 0.025 US $ 3.75

iv. Labour (day-basis)

	Shifts	Men	US $ per day	$ Total per day
1. Grinding and weighing	1	5	0.75	3.75
2. Mixer and ball mill	3	3	1.25	3.75
3. Noduliser and homogeniser	3	3	1.50	4.50
4. Kiln operator	3	3	2.50	7.50
5. Clinker and cement mill	3	6	1.00	6.00
6. Silos	3	3	1.00	3.00
7. Packaging	1	1	1.00	1.00
8. Extras	3	6	1.00	6.00
		30		35.50 per day

Day labour will cost US $ 35 per day or US $ 14/t cement.

v. Staff (monthly salaries):

	Mon.	US $ per month	Total per month
1. Manager	1	187.5	187.5
2. Mechanical Engineer	1	150.0	150.0
3. Supervisors	3	100.0	300.0
4. Chemist	1	125.0	125.0
5. Workshop machinist	1	75.0	75.0
6. Lab. assistants	3	50.0	150.0
7. Electrician	1	62.5	62.5
8. Assistant mechanic	1	50.0	50.0
9. Accountant	1	87.5	87.5
10. Cashier	1	50.0	50.0
11. Clerk	1	50.0	50.0
12. Stenographer	1	75.0	75.0
13. Typist	1	50.0	50.0
14. Night guard	3	25.0	75.0
15.	1	25.0	25.0
	21		1,512.50

US $ 1,512.5 per month is equivalent to US $ 2.25 per ton cement.

vi. Overhead

Overheads. office expenses. contingency of 20% on total labour costs.

Day labour	US $ 1.40
Staff	US $ 2.25
	US $ 3.65/t
Overheads	US $ 0.75/t

vii. Stores and repairs

Taken on a per annum basis

Buildings 2% on US $ 37,500	US $ 750
Machinery 4% on US $275,000	US $ 11,000
	US $ 11,750

On a per ton cement basis this is equivalent to US $ 1.45/t.

viii. Summary of running costs per ton cement

	US $
Raw materials	8.22
Fuel	1.96
Power	3.37
Labour (day)	1.40
Labour (month)	2.26
Overheads	0.75
Repairs and stores	1.46
	US $ 19.42

say US $ 19.50 per ton cement.

4. Gross annual surplus

In fuel production gross annual surplus will be

Gross sales	US $ 220,000
less running costs 8.00 x $ 19.50	US $ 156,000
Gross annual surplus	US $ 64,000

This represents a gross return of 20.5% on capital invested, which is roughly what the Cement Corporation of India expected to earn on a large plant.

Deduct the depreciation on building at 5% of $ 37,500 = 1,875
machinery at 10% of $268,750 = 26,875
US $ 28,750

Net return = $ 64,000 - 28,750 = 35,250

Return on capital 9.4%

APPENDIX - II

Some data on comparative costs of production in large and small scale cement plants in India (collected by Robert Bruce, May 1975).

Estimated costs of production for cement to be produced in the proposed 25 t/d vertical shaft plant have already been produced. The following is some data supplied by the Cement Corporation of India on estimated costs of production in an average 1200 t/d Humboldt type wet process rotary kiln plant, of the type CCI are currently installing in India.

1. Annual production
   340,000 tons of cement
2. Capital cost (May 1975)
   US $ 30 million
3. Workforce and wages
   630; minimum wage $ 75 p.m.
4. Fuel consumption
   4795 - 5212 kJ/kg clinker
5. Power consumption
   140 kwh/t cement
6. Raw material reserve required
   24,000,000 tons of limestone
7. Market supplied
   Average per capita cement consumption in India is about 30 kg p.a. This plant, therefore, supplied about 11 million people (as compared to about 250,000 for a 25 t/d plant)
8. Approximate costs of production were as follows (May 1975):

a. Manufacturing

	US $ per ton	(% of total)
Limestone	1.87	
Gypsum	0.50	
Coal	2.25	
Power	2.12	
Stores and repairs	1.75	
Salaries and wages	1.37	
Overheads and Misc.	1.00	
	10.86	(29%)

b. Packing and transport

Packing	5.00	
Transport	4.00	
	9.00	(24%)

c. Capital

Gross capital	17.62	
Cost at 20%	17.62	(47%)

d. Total cost per ton

to consumer	37.50	(100%)

9. CCI indicated that in practice they do not earn 20% (gross) on capital, sometimes as little as 10-15%.

10. From the above it can be seen that a small scale plant with a capital investment per ton of annual capacity of about ½ the large scale figure US $ 43.75 as opposed to US $ 87.50 has a good chance of competing successfully because capital costs account for nearly 50% of the above cost of production.

11. Furthermore, a small plant will tend to have considerable advantages in the packing and transport items, as they will be able to sell their produce to local markets. Packing and transport account for 25% of the above local cost of production, and are thus an important part of the whole

12. CCI said that it takes four years to erect and a further one year to run in those 1200 ton plants which means a long wait for any cash to flow back and consequently the discounted rate of return is considerably lower than the straight % on capital used above.

13. It therefore seems quite possible for a 25 t/d kiln plant to compete with the large rotary plants, because of the much lower capital costs per ton a nual capacity and lower transport and distribution costs.

14. N.B. Their costs were as in May 1973. Costs estimated for the 25 t/d plant are based on 1977 prices, and are excluding transport and packing which would add about US $ 10 per ton making about US $ 47.5 per ton. Allowing for two years inflation at 25-30%, the cost of production in the CCI rotary plants now will be US $ 46.8 - 48.8 per ton, i.e. just about the same as the 25 t/d plant estimate.

15. There is a large difference between the two types of plant in the employment and value added generated in the locality of the plant. The small plant generates far more direct employment per unit investment than the large plant, and because the machinery is less sophisticated maintenance services and stores can be supplied by local firms.

16. The following figures summarise the data on the two types of plant:

	25 t/d vertical shaft	1200 t/d rotary
1. Annual production (t)	8,000	340,000
2. Capital investment	US $ 2.5 mill.	US $ 240 mill.
3. Capital investment per worker	US $ 6,000	US $ 47,620
4. Jobs per million $ invested	168	20.8
5. Ration of above	8.08 : 1	
6. Population supplied by one plant	250,000	11 million
7. Jobs per thousa d tons produced annually	6.5	1.85
8. Ratio of above	3.51 : 1	
9. Raw material reserve required by one plant (40 years output) tons	528,000	24 million

APPENDIX - III

GLOBAL SURVEY OF VERTICAL SHAFT KILNS

Country	Number of locations	Number of active kilns	Capacity tons 10	Production tons 10
Algeria	1	1	50	n.a.
Kenya	1	6	700	630
Morocco	1	1	140	116
Rhodesia	1	2	316	269
Zaire	1	4	280	286
Iran	1	2	n.a.	n.a.
Japan	1	10	n.a.	542
Australia	1	2	n.a.	n.a.
Belgium	1	3	n.a.	84
France	7	28	n.a.	n.a.
Fed.Rep.Germany	8	39	n.a.	n.a.
Hungary	1	5	300	n.a.
Italy	24	45	n.a.	n.a.
Poland	1	6	192	148
Spain	14	37	n.a.	n.a.
Switzerland	1	1	55	36
Yugoslavia	7	29	n.a.	n.a.
	72	221		

Estimated capacity 10,000

Source
World Cement Directory
The European Cement Association
Cambureau, Paris 1972

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