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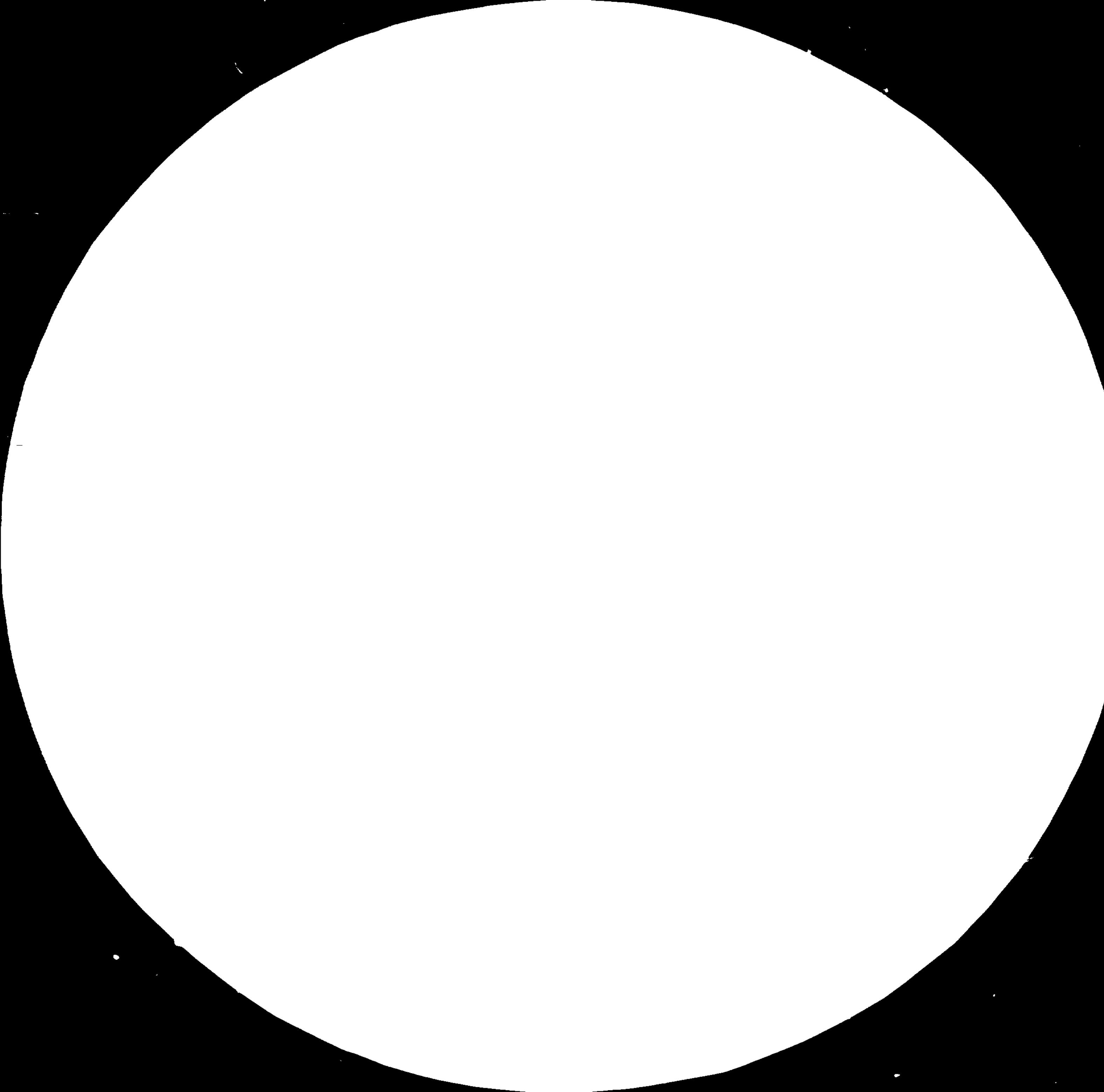

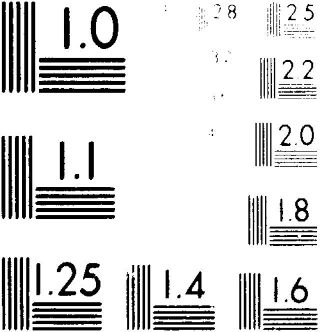
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UNITED NATIONS INDUSTRIAL
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Libya. ASSISTANCE TO THE LIBYAN CEMENT FACTORY, BENGHAZI.

TF/LIB/75/002

LIBYAN ARAB JAMAHIRIYA

Prepared for the Government of the Libyan Arab Jamahiriya
by the United Nations Industrial Development Organization

Based on the work of Abd El Rahim Marei,
UNIDO adviser

V.81-28033

Explanatory notes

References to tons (t) are to metric tons.

References to dollars ($) are to United States dollars.

The following technical abbreviations are used in this report:

BS	British Standard
CES	computerized evaluation system
t/h	ton per hour
kcal/kg	kilocalorie per kilogram
kWh/t	kilowatt-hour per ton
t/d	ton per day
t/a	ton per year
LSF	lime saturation factor
SM	silica module
AM	alumina module
L.O.I.	loss on ignition

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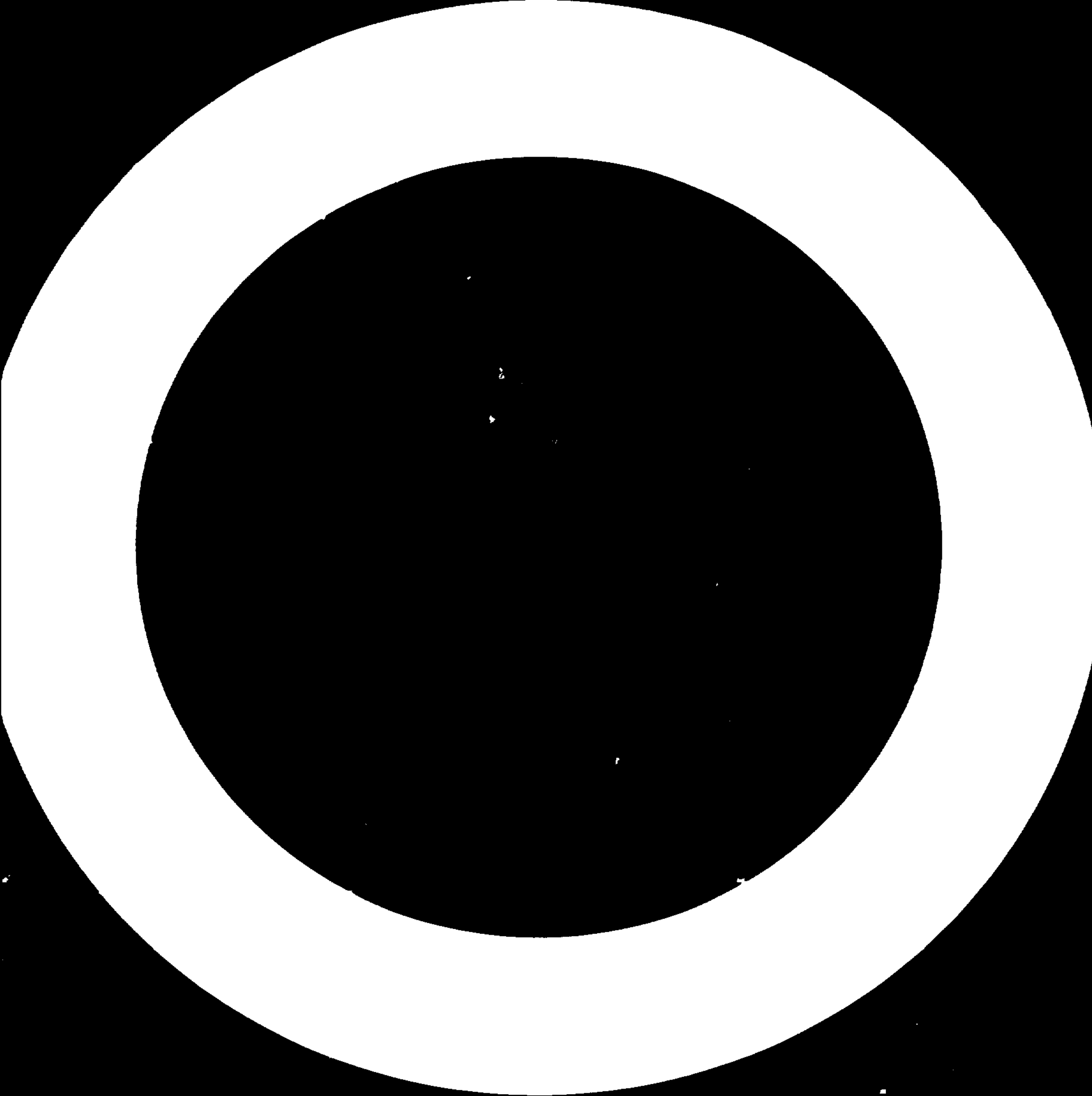
ABSTRACT

The project "Assistance to the Libyan Cement Factory, Benghazi" (TF/LIB/75/002) began as a minor technical activity in 1976 and is financed by the Government of the Libyan Arab Jamahiriya through a trust fund arrangement with the United Nations Industrial Development Organization (UNIDO). It now has a total budget of over $8 million. Its aim is to assist the Libyan Cement Company to develop and expand its complex of cement and building materials industries in the Benghazi area.

The expert is co-ordinator of UNIDO technical activities being introduced to the fields of technical assistance. He also advises his national counterparts on technical matters related to cement production.

After comparing the chemical composition of raw materials deposits at Wadi Ash Shati and El Gufra, the expert concluded that exploitation of the latter would be more advantageous for supplying a cement plant with a capacity of 0.5 million tons over a period of 50 years.

At the request of the Libyan authorities, the expert was asked to evaluate which of the raw materials (based on two reports carried out by Polservice) predominating in Wadi Ash Shati and El Gufra area were more suitable to supply a new cement plant of a capacity of 5 million tons to be erected in the area. The expert concluded that the exploitation of the latter would be more advantageous.



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INTRODUCTION

The present report on the project "Assistance to the Libyan Cement Factory, Benghazi" (TF/LIB/75/002) is an evaluation of two reports prepared by Polservice on the supply of raw materials for the cement and lime industry in the Libyan Arab Jamahiriya, at two sites: Wadi Ash Shati and El Gufra.

The project is financed by the Government of the Libyan Arab Jamahiriya through a trust fund arrangement with UNIDO which now has a total budget of over $8 million. Its aim is to assist the Libyan Cement Company develop and expand its complex of cement and building materials industries in the Benghazi area.

The expert was appointed co-ordinator of the project on 10 May 1980 for a period of 18 months, finance to be provided from overhead costs. His duties are to follow up and monitor the work of specialists assigned to the building materials industry complex in Benghazi, and specifically he is expected to:

(a) Assist Libyan counterparts in technical and administrative matters;

(b) Follow up and control the functioning of specialists;

(c) Give technical and administrative assistance;

(d) Facilitate the implementation of UNIDO activities being introduced to the fields of technical assistance.

Industrial development began in the Libyan Arab Jamahiriya, at Benghazi in 1972, with the start of the first rotary kiln with an annual production capacity of 200,000 tons. After rapid growth the annual capacity reached 2 million tons.

Industrial growth and the increasing need for trained staff made it necessary to request technical assistance and to initiate training for national personnel. The UNIDO project began in November 1976 with a building materials adviser and by March 1981 had grown to comprise 73 experts covering various industrial activities in the field of cement and the building materials industry under the control of the Libyan Cement Company, Benghazi. It is planned to expand this number to 100 experts with diversified specializations.

FINDINGS AND RECOMMENDATIONS

The chemical composition of the raw materials at the Wadi Ash Shati deposits shows complex and heterogeneous characteristics, while the El Gufra deposits are homogeneous. The raw materials predominating at El Gufra will make it possible to ensure even kiln operations.

Exploitation of the Wadi Ash Shati quarries will be complicated and difficult; El Gufra on the other hand will be easy to exploit and this can be carried out in the normal way.

Conglomerate, chert, sandstone and quartz contaminated and intercalated with most of the raw materials at Wadi Ash Shati will create many problems. These hard materials will act in an abrasive manner against the crushers, the lining and the grinding media. An 8% additive to the El Gufra sands will increase the silica modulus without any harmful effects.

The overburden overlying the proved and probable reserves at the Wadi Ash Shati raw material deposits contains harmful foreign materials. Careful mining and quarrying will be required before exploitation of these raw materials can be effected satisfactorily. The overburden covering the El Gufra raw materials is not harmful compared with the Wadi Ash Shati deposits.

Raw material reserves, whether proved or possible at El Gufra are sufficient to supply an 0.5 million ton capacity plant with its requirements for more than 50 years. With respect to Wadi Ash Shati, the raw material reserves are subject to further exploration and investigation to ensure that possible and probable reserves will not be reduced in the proved category, i.e. proved raw materials are required to permit 0.5 million ton clinker production for at least 50 years.

Galmoya iron ore was examined as the possible ferruginous additive required for correcting the Fe_2O_3 content of the raw materials in both areas. It was considered to be a high quality iron ore which could supply the needed component to raw materials deficient in iron oxide; it contains about 70% Fe_2O_3.

Laboratory and technological tests of the raw materials, to investigate their suitability for Portland cement clinker production at Wadi Ash Shati as well as El Gufra, showed that they are suitable for the preparation of the raw mixtures necessary for the production of normal Portland cement clinker with the following assumed parameters: LSF = 0.93, SM = 2.6, AM = 2.0.

The raw mixtures were prepared according to the above parameters from both raw material deposits at Wadi Ash Shati as well as El Gufra. These are characterized by normal burnability, and would present no problem when burned in cement kilns.

The raw mixture designs indicated that the accompanying components, Mg, SO_3, Na_2O, K_2O do not exceed the acceptable limits, on the other hand, chlorine content at both sites was rather high. Adequate by-pass techniques are therefore required.

The data concerning the quality of the gypsum at Hun or the Socna region are satisfactory. Special attention has to be paid to the Socna gypsum when blending it.

Limestone in the Gufra region only will be suitable for lime production as this is considered to be of a high quality.

It is recommended that a study should be made of the market for cement in the central part of the Libyan Arab Jamahiriya. The study should consist of the estimated per capita consumption and should include a forecast based on, needs in the next 10 years derived from an analysis of the statistics involved, reinforced steel bar consumption, gross investment in building and construction activities and the possibility of exporting cement to Chad and the nearest southern countries.

A decision concerning the capacity of the proposed cement plant could then be taken without hesitation.

A comparison of raw materials in the two areas - Wadi Ash Shati and El Gufra - showed that the latter's raw material deposits were more feasible for cement production, and it is accordingly recommended that a cement plant be established in that area after the following activities have been carried out:

(a) About 1.75 million tons of raw gypsum is required to be proved by means of concentrated drilling in a selected area of the rift valley;

(b) Applying adequate "by-pass" techniques when selecting the kiln;

(c) Installing a simple station equipped with an X-ray analyser and a mini computer in front of the stock pile.

If the decision were to select a cement plant with a capacity of less than 300,000 tons because of an estimated modest consumption in that area in the next 10 years, it is recommended to study the possibility of establishing a small-scale plant as an alternative solution.

A feasibility study based on the availability of fuel, water, power supply, roads and transportation is also recommended.

I. WADI ASH SHATI DEPOSITS

A. Marketing outlook

The main factors influencing a demand for establishing a cement plant in the area are:

(a) Present and future requirements with regard to cement, i.e. marketing study is required before any investigations have to be undertaken on the raw materials required for cement production in the selected area. The main factors greatly influencing cement marketing are:

(i) Average per capita consumption of cement;

(ii) Reinforced steel bar consumption;

(iii) Gross investment in building and construction activities;

(iv) Time factor;

(v) Cement price.

(b) A specific area has to be selected depending on the results of the marketing study. Geological investigations, followed by regional explorations to determine prospective areas for the exploration of raw materials, have to be carried out.

The final report by Polservice indicates that a dynamic development of all branches of the economy in the Libyan Arab Jamahiriya foreseen is in the long term, especially in the field of agriculture, building and engineering. This will create an increased demand for building materials, including cement.

Existing cement plants and those to be commissioned in the near future will not be able to prove sufficient to meet the growing demand. The shortage will have to be supplemented by means of costly imports from countries willing to dispose of their cement surpluses. The lack of cement is especially felt in the Fezzan area, where it is planned to further develop agriculture, animal husbandry as well as housing.

The report concluded that the best solution for the Fezzan area would be the erection of a local cement plant, and that the cost of construction would be repaid within a period of about 8 years. This would be as a result of savings obtained by not requiring transport charges from the north of the country.

Comments

The long term plans of the Libyan Arab Jamahiriya in the field of agriculture, building and engineering are not available for study. It is, however, necessary to mention the existence of data concerning the influence of agriculture and building engineering on future cement demand.

There is no data to confirm that the existing cement plants and those designed to be commissioned in the near future will not be able to meet the growing demand for cement. The author believes that in the near future, after the new cement plants are commissioned, the Libyan Arab Jamahiriya will have sufficient cement as well as a surplus supply for export.

After taking into consideration what has been mentioned in the final report now under study, it is the author's opinion that based on the available data, there are two questions to be answered: Is it possible to construct a cement plant of 0.5 million tons capacity? Is it possible to utilize all the cement produced after the erection of such a cement plant in this area?

In concluding these comments it seems essential that a marketing study be undertaken in order to assess the cement demand of this sector in the Libyan Arab Jamahiriya over the next 10 years.

B. Raw materials

Investigations of raw materials and chemical composition carried out by Polservice Geopol on Wadi Ash Shati showed complex and heterogenous characteristics. The mixtures consisted of four raw materials: (a) Limestone; (b) Conglomerate; (c) Clay; (d) Iron ore (Galmoya).

The chemical composition of the limestone, predominating in cross-sections, shows variable changes, especially in the silica content which fluctuates between 4.94 and 9.02%. Although the variations in the silica content are obvious, they are complicated and show heterogeneous characteristics in the drilled boreholes in the silica as well as the CaO content. The silica content increases in some boreholes to reach 21.02% while the CaO content decreases to 39.75% (the limestone is the main part in the raw mix and ranges between 73.77-80.69% according to the mean chemical composition of the cross-sections).

Limestone of the Upper Cretaceous period forms the topmost series. It is cohesive, locally slightly sandy, with fine cherts. The limestones are fine, crystalline and cryptocrystalline; white and greyish-white with rosy streaks.

The lower part of the Upper Cretaceous formation consists of conglomerates composed of boulders and gravels of sandstone, sandy mudstones, quartz, claystones, as well as ferruginous sandstones, all cemented by a calcareous matrix. The conglomerates with the calcareous matrix make up occasional interbeddings in the above-lying Upper Cretaceous limestone. The chemical composition of the conglomerate which appears in cross-sections shows variations in its constitutents, especially the SiO_2 content which oscillates between 21.03-29.3%, while the CaO content changes between 33.17-39.92%. The variations in the drilled boreholes are obvious and show wide ranges. Some boreholes reveal the following chemical analysis (figures in per cent):

SiO_2	CaO	Al_2O_3
78.47	0.00	10.19
76.08	0.00	12.36
71.50	1.29	13.14
43.77	28.05	
31.3	29.58	

Clay forms an important key bed recognized in many boreholes as covering "roof beds"; these begin with fine-grained lamellar sandstones and sandy mudstones of Bifungites fezzanensis desio. The clays are grey, dark-grey and olive-coloured. The clays are intercalated with mudstones and fine-grained sandstones, locally ferruginous.

The chemical analysis of the clays shows more or less stable homogeneity. The SiO_2 ranges between 54.6-55.9%, while the alumina content varies between 20.78-23.6%. The Fe_2O_3 fluctuates between 7.24-8.19%.

Comments

It is expected in the future that exploiting such a quarry would be complicated and difficult. Accordingly, a feasibility study on the exploitation of the quarry and blending of raw materials is required. The introduction of the F.L. Smidth Computerized Evaluation System (CES) could give marked progress in the field of raw material exploitation as it enables the processing of a large amount of data, selecting from an infinite number of calculation results the optimum solution to a specific problem to ensure steady kiln operations; this being the object of exploitation research. The fluctuations in the analyses, and before applying the CES system, close-spaced drilling, are needed before exploitation.

The report under study indicates that the proportions of raw materials will be as follows, taking into consideration the fact that variations according to the cross-section's chemical analysis are limited:

(a)	Limestone	66-88%,	average	79.5%;
(b)	Conglomerate	0-21%,	average	7.6%;
(c)	lay stone	10-14%,	average	12.4%;
(d)	Iron ore	0.2-0.8%,	average	0.5%.

The blending of such complex heterogeneous raw materials requires, before stock-piling, a sample station which has to be installed and equipped with an X-ray analyser and a mini computer (discontinuous multi-channel equipment for off-line use, with eight channels for determination of Ca, Si, Al, Fe, Mg, K, Na and Cl.

The chert, conglomerate, sandstone, quartz contaminated and intercalated with most of the raw materials will create many problems as these hard materials will act as abrasive materials in relation to the crushers, whether hammer, jaws or gyratory. These abrasive materials will act also on both the raw mill lining and the grinding media. Thus, the consumption of the mill liners and grinding media will increase normal consumption to a certain extent more than usual. At the same time, it is noteworthy to mention that sandstone, quartz, chert (if present in some patches) in high percentages, will leave and add some remnants to the grinding media as the grindability of the raw materials are of different hardnesses.

The quantities, i.e. all the raw material reserves proved or probable, are sufficient to supply a cement plant with a capacity of 0.5 million tons with its requirements. It is stated in the report that probable reserves will not be less than the proved amount.

The raw mixtures, as shown in the report, indicate that the accompanying components of Mg, So_3, Na_2O, and K_2O do not exceed the acceptable limits.

The chlorine content in the raw mixtures is rather high, and the author agrees with the report's proposal to apply an adequate "by-pass" technique.

The overburden overlying the proved and probable reserves is worrying. This overburden is harmful to the raw materials required for the production of cement. To eliminate it will take time and money. Careful mining, quarrying and special trucks are required. It is worthwhile also noting that the interbedding of dolomitic limestone under limestone and above clay strata will create many problems and this must be carefully removed as an overburden bed.

No satisfactory data were given in the report concerning the gypsum and iron ore in Hun and Galmoya, respectively, except the following:

(a) Opening of the gypsum quarry in the Hun region in order to secure raw materials for cement manufacturing;

(b) The chemical analysis at Gammoya is shown as follows (figures in per cent):

L.O.I.	14.0
SiO_2	4.7
Al_2O_3	3.5
Fe_2O_3	71.0
CaO	2.8
MgO	1.5
SO_3	0.1
Cl	0.42

The quantities and qualities of the two raw materials necessary for cement production are not felt to be satisfactory, and more data concerning these raw materials are required to ensure their availability for cement production within the life of the plant.

The study must also deal with economic factors as well as the availability of fuel, water, electricity supply, roads, transportation costs etc., before reaching any decision on whether or not to construct a plant with a capacity of [illegible].5 million tons.

Laboratory and technological tests of raw materials from the Upper Plateau and Mahruga "Field A" deposits showed that the raw materials were suitable for the preparation of raw mixtures for the production of normal Portland cement clinkers with the assumed parameters: LSF = 0.93, SM = 2.6, AM = 2.0.

The raw mixtures prepared from the raw materials from both deposits are characterized by normal burnability, and there should be no problem with regard to burning in industrial kilns.

The chlorine content points to the necessity of applying "by-pass" procedures.

The limestone is not suitable for lime production because of the presence of foreign materials in variable percentages.

II. EL GUFRA DEPOSITS

As stated in the marketing outlook for the Wadi Ash Shati cement plant project, it is important to emphasize the fact that a marketing study ought to begin by assessing the market for cement and its capacity in the central part of the Libyan Arab Jamahiriya.

It is proposed that a study be undertaken of the actual cement per capita consumption, and a forecast be made of the needs in the next 10 years based on an analysis of the statistics involved, the reinforced steel bar consumption, gross investment in building and construction activities, and the possibilities of exporting cement to Chad etc.

The author's comments with regard to the economic conclusions concerning the Wadi Ash Shati cement project are the same as far as the El Gufra cement plant project is concerned.

A. Raw materials

Mixtures consist of the four raw materials: (a) Limestone; (b) Marl; (c) Sand; (d) Iron ore.

The properties of the raw materials are as follows:

Limestone

The limestone comes from the highest part of the Upper Tar Member (Upper Plateau), the thickness of which ranges from 22.3-26.4 m, an average of 24.5 m. Its colour is yellowish, yellowish-white and creamy, it is a cryptocrystalline, slightly porous limestone lamellar and compact in the upper part.

The CaO content ranges from 52-53%, and shows homogeneity and little variations in quality in all the boreholes; it can be considered as a high-grade limestone.

Exploitation is simple because the geology and concordant stratification of the studied area are straightforward. The proved reserves are estimated to be over 18 million tons while the possible reserves are over 15 million tons.

Other limestones on the uppermost part of the lower plateau deposit also display an average content of more than 52% CaO with one exception in borehole no. J-6/9 where the average CaO content amounts to 51.7%. Such high-quality nodular limestone also qualifies it for cement clinker production.

Depending on the design of the raw mix it was calculated that in special cases it was easy to exceed the acceptable limits of MgO content in clinker. This can be avoided by precise control of the chemical composition of the two main components, limestone and marl, and by means of selective exploitation, prehomogenization, drilling additional boreholes to assess further the MgO content of both the limestone and the marl. The possible reserves of nodular limestone were calculated at over 11 million tons.

Marl

The upper marl deposits display an average thickness of 19 m. The lower part of this sequence is built of grey, greyish-green and olive-coloured clayey marls and marly claystones.

The average chemical analysis in percentage terms of the proved and possible reserves is as follows:

	Proved	Possible
L.O.I	32.12	31.67
SiO_2	17.09	16.95
Al_2O_3	8.28	8.56
Fe_2O_3	2.72	2.68
CaO	35.72	35.27
MgO	2.26	2.73
SO_3	0.35	0.25

The silica content of marl in the drilled boreholes ranges between 14.25-18.94%, while the alumina content fluctuates between 6.66-10.53%. The Fe_2O_3 content is between 2.31-2.95%. CaO and MgO contents are between 33.4-39.33% and 1.76-3.06% respectively. Proved reserves of upper marl were calculated as over 20 million tons, while possible reserves totalled over 18 million tons.

The lower plateau upper claystone chemical analysis showed the SiO_2 content ranges between 25.39-44.3%, while the Al_2O_3 content ranges between 15.48-22.51%. Fe_2O_3 content fluctuates between 4.69-9.16% and CaO is within 9.98-16.09%. The MgO content reaches a minimum of 1.69% and increases to more than 3.60%.

The chemical composition of the upper claystone as well as the minimum and maximum composition of the constituents in percentage terms were as follows:

Thickness		L.O.I.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
Average	4.63	18.9	34.16	18.16	6.2	16.05	2.55
Minimum	3.5	13.1	25.39	15.48	4.69	9.98	1.69
Maximum	6.6	24.09	44.30	22.51	9.16	24.03	3.63

Calculated possible reserves were estimated at over 8 million tons.

<u>Sand</u>

Raw mix designs show that the main raw materials, limestone and marl need corrective materials to increase their SiO_2 and Fe_2O_3 content in order to blend adequately. Sand dunes as a source of siliceous corrective materials, located not far from the main deposits and stretching along the Waddan - Bu Ghren road were proposed as a possible source of supply. Sand from these dunes is quite homogeneous in chemical composition and grain-size distribution. The grain ranges in size from 0.06-0.25 mm. Chemical analysis of the sand was as follows:

Thickness	L.O.I.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3
Average	5.21	84.9	1.63	0.56	5.89	0.91	0.16
Minimum	3.66	78.14	0.65	0.3	4.47	0.61	0.07
Maximum	6.65	87.56	4.73	0.89	7.70	1.12	0.28

The analysis indicated that this type of sand is suitable and would increase the silica modulus to the required limit.

The possible surface reserves covered 327,840 m^2, and actual reserves were estimated at over 7 million tons.

Gypsum

Tertiary gypsum deposits occur in the central part of the Hun rift valley. At the base of the gypsum strata are grey agglutinations with fauna of molluscs as well as greenish-grey marls.

The overlying gypsum is white, slightly sandy and clayey in places with intercalations of greyish-brown claystones and cherts. The thickness of the gysum sequence is up to 27.3 m; the possible reserves amount to a minimum of 17 million tons, and it is not covered by an overburden.

Another source of gypsum ore for regulating the setting time of cement was investigated in the Socna region. Chemical analysis was as follows:

H_2O 50°C	H_2O 250°C	SO_3	CaO	MgO	SiO_2	Al_2O_3	Fe_2O	L.O.I.	$CaSO_4.2H_2O$
0.5	18.0	38.4	26.9	1.0	10.4	1.6	0.6	1.4	82.6

The quality of the gypsum was satisfactory and it can be used as in other types of gypsum as a setting-time regulator. It is necessary to pay special attention to blending the gypsum as the $CaSO_4.2H_2O$ content varies. The extent of the reserves is not mentioned in the report, and further exploration is needed to assess the gypsum deposits in this area.

B. Iron ore

Galmoya iron ore is considered to be ferruginous corrective raw material and it is commonly used as such in the Libyan Arab Jamahariya in the cement industry.

Comments

On the basis of these investigations of raw materials it can be stated that:

(a) The qualitative variations of raw materials in the prospected deposits show some changes. From the raw mixes, additives are needed to increase the silica modulus as well as to increase the iron content. Accordingly, four types of raw materials are required to produce normal Portland cement which complies with British Standard (BS) specifications, as follows:

(i) Limestone from either the upper plateau, the lower plateau or Socna (lower plateau);

(ii) Marl from either the upper marl deposits or the lower upper claystone from the lower plateau;

(iii) Sand from the dunes along the Waddan - Bu Ghren road;

(iv) Galmoya iron ore.

(b) Although these four materials will enter the raw mix, their homogeneity will make it easy to ensure steady kiln operation;

(c) It is recommended to facilitate correct proportioning of these materials that before a stockpile is created a simple station equipped with an X-ray analyser and a mini computer is installed (discontinuous multichannel equipment for off-line use, having eight channels for determination of Ca-Si-Al-Fe-Mg-K-Na-Cl);

(d) Exploitation of the quarries will be easy and can be conducted in the usual way;

(e) The proportions in percentages of the raw materials will be within the following limits, assuming LSF = 0.93, SM = 2.6, AM = 2.0:

Upper plateau

	Limestone	Marl	Sand	Iron ore
Proved	54.5	36.7	8	0.80
Possible	54.78	36.4	8	0.82

Lower plateau

	Nodular limestone	Marl	Sand	Iron ore
Proved	74.0	15.8	9.5	0.7
	Scona limestone			
Possible	77.8	12.5	9.6	0.1

The percentage of sand and iron ore used as additives will be 8% and 0.8-0.82% respectively, which means simple blending and treatment. For the lower plateau, the treatment to some extent will be difficult;

(f) Raw material reserves (proved and possible) are sufficient to supply an 0.5 million tons capacity cement plant for more than 50 years;

(g) Blending of raw mixtures of Socna limestone and upper claystone needs attention in order to control and regulate the MgO content;

(h) Data concerning the gypsum deposits in Hun and the Socna region are satisfactory. Special care has to be paid to Socna gypsum when blending it;

(i) The economic study must cover the availability of fuel, water, electricity, power, roads and transportation costs before any conclusion is reached on the establishment of a plant with a capacity of 0.5 million tons;

(j) Laboratory and technologial tests showed that the raw materials were suitable for the preparation of raw mixtures and for the production of normal Portland cement clinkers with the assumed parameters: LSF = 0.93, SM = 2.6, AM = 2.0.

The raw mixtures prepared from these materials are characterized by normal burnability, and no problem should be met when burning them in cement kilns.

The chlorine content indicates that it is necessary to apply "by-pass" procedures;

(k) The limestone is suitable for the production of lime.

III. PROPOSAL

The central region of the Libyan Arab Jamahiriya is developing such activities as agriculture, animal husbandry, housing and social building construction, and as a result the supply of cement to this region depends upon deliveries from the north of the country. The distance between these two regions is vast and the cost of transportation considerably exceeds the cost of the cement. On one hand this causes increased costs of building, and on the other, transportation of cement involves a great number of workers and transport facilities.

Investment efficiency (production capacity per unit invested) is extremely important for any factory because of the difficulty in obtaining the necessary financial support unless the feasibility of the project was proven beyond all doubt. If the recommended marketing study concludes that consumption in the central region would be modest and would not exceed 0.5 million tons over the next 10 years, the capacity of the plant will have to be reduced and a small-scale cement plant is proposed as an alternative solution. The following proposal is based on the information paper published by UNIDO, by H.C. Boeck and H. Klatt (UNIDO/IOD.48/Rev.1, 16 January 1981).

The paper indicates that increasing transport costs and modest cement consumption have created a demand for decentralization of cement plants in various developing countries, particularly, in the least developed countries and regions.

In order to produce low-cost cement it is necessary to construct units as close as possible to the raw material supplies and either close to the market or to some means of inexpensive transport. This is an alternative to large production which enables capital investment to be kept low and keeps fixed costs down.

To reduce costs it is essential to reduce the need for heavy equipment and to establish a high degree of standardization in equipment design and production. Complex and sophisticated equipment and large factory lay-outs should be avoided.

Experience in building and operating small-scale cement plants has been obtained in China, where about 3,400 shaft kiln plants are in operation in the 3,000-7,000 t/a range, the 10,000-50,000 t/a range and the 50,000-100,00 t/a range. Of the total production of 74 million tons of cement in 1979, approximately 50 million tons were produced by shaft kilns.

European experience in building and operating shaft kilns is as old as cement production, but only one supplier still offers complete plants. This supplier is actively involved in building new plants and the black meal process technology involved is well liked by users.

As well as small-scale shaft kilns, small-scale rotary kiln technology is offered by several companies. No up-to-date experience regarding the investment costs of the new so-called compact cement plants is available, but some companies claim that they are able to build similar plants to shaft kiln installations at a similar cost.

Until such figures are available it is anticipated that higher initial costs in this respect will occur (see annex I).

IV. BACKGROUND

The investment cost in the cement industry is generally high; thus it is important to standardize and to determine the most economical and suitable size for small-scale factories in order to make savings. The 60,000-120,000 t/a range from two conventional shaft kilns seems to be the most suitable size.

For conventional shaft kilns a low-volatile fossil fuel, with less than 20% volatile matter, will have to be used. If this is not available the problem may be solved by charring high-volatile fuel; the volatile gases could be burned and used for drying the raw materials. Such a system has worked successfully since 1965 at the Gippsland Cement Plant, in Victoria, Australia. The plant is using charred brown coal briquettes as fuel for its two shaft kilns.

For this shaft kiln system it is necessary to produce pellets or nodules, which are small balls, 1/2 inch (12 mm) in diameter, of uniform quality and high strength, consisting of ground raw materials and 12-18% water. If the formation of nodules of sufficient strength and heat resistance is not possible, a rotary kiln process is mandatory.

A small-scale plant producing 120,000 t/a would be the ideal size. The cost of machinery for the shaft kiln incorporating a cooler would amount to approximately 4-6% of the total investment cost, whereas that of a rotary kiln plant would be approximately 8-10%. The advantages of a shaft kiln installation would be:

(a) Substantial savings in space;

(b) Simple construction with no heavy castings;

(c) Few problems with starting and stopping;

(d) High degree of reliability due to the durability of refractory bricks;

(e) The kiln and the cooler is an integrated (combined) unit;

(f) Low alkali clinker could be produced;

(g) A high degree of do-it-yourself construction could be developed. This is necessary to reduce the total investment cost. The fuel (coal) in sizes of 1.5-2.5 mm is introduced directly to the pan pelletizer together with the raw mix.

Rotary kiln technology is reliable and a small rotary kiln plant, despite its high costs helps to familiarize the operators with a technology that may be applied sooner or later in the plant's expansion when the cement market develops after the plant's installation.

Efficient operation of a shaft kiln requires adequate distribution of air in the burning zone. This can be facilitated with a good discharge grate. Efficient operation of equipment for the preparation of raw materials, also helps in producing good quality, low alkali clinker in a shaft kiln (semi-dry process). Pre-blending of the limestone is highly recommended either for a rotary kiln or for a shaft kiln.

V. CAPITAL INVESTMENT FOR NEW CEMENT PLANTS

Once finance is secured, the fixed costs required for amortization will influence the price of the final product. The technology for the shaft kiln appears to have an edge over that for the rotary kiln.

The costs of vertical kiln plants are compared with rotary kiln plants in annex I.

Manufacturers of rotary kiln plants with preheaters and calciners prefer not to use kilns of a capacity below 800 tons per day (t/d), because:

(a) Cyclones are small and jamming might reduce the efficiency of the plant;

(b) In the case of frequent stoppages, because of blocking of cyclones, fuel consumption might be higher than anticipated;

(c) By-pass installations might be necessary in order to control the quality, and additional investment costs might make the factory proposed less feasible;

(d) Bricklayers are reluctant to make repairs in the preheater and calciner because there is very little working space.

Nevertheless, it is technically possible to produce small, reliable dry-process cement plants without preheaters; the important point is to have accurate information about investment and operating costs and to compare different proposals before a final decision is made.

VI. ROTARY KILN WITH PREHEATER AND CALCINER

It should not be forgotten that the 1950s-type small-scale rotary kilns are still technically possible to build. The only problem is that they are now relatively expensive (investment costs per ton capacity).

Some companies have begun to examine the possibilities of simplifying the techniques for operating small rotary kiln plants, utilizing modern know-how, in order to offer an economic solution for the construction of small cement factories.

VII. COMPACT SHAFT KILN CEMENT PLANTS

Many developing countries, particularly the least developed countries, have not sufficiently developed their cement industry. In many cases they have difficulties in identifying a balanced approach which will yield the necessary financial support.

Cement demand is often too little and too thinly spread over a large area to justify a medium- or a large-scale plant, and increasing transport costs work against centralized production.

When both production and transportation costs are analysed, the conclusion is reached that decentralized production in small-scale plants is advantageous. The socio-economic factor in creating employment centres in rural areas should also not be under-estimated.

The shaft kiln technology has been used for nearly a century, but in the early 1960s the lay-out and design of shaft kiln plants reached a high level. This period coincided with the introduction of the dry-process, four-stage suspension, preheater kiln that made it possible to avoid increasing cement prices drastically by the use of large and economic production units. The shaft kiln then began to lose popularity, particularly as transport costs were then relatively low.

There are, however, cases where a shaft kiln is the best and the most economic solution. Quality clinker produced by a shaft kiln can be as good as clinker produced by a rotary kiln, provided the same care is taken in the preparation of the raw materials. In order to produce good shaft kiln clinker the following conditions will have to be fulfilled:

(a) Plasticity of the raw materials, particularly the clay, in order to make pellets of sufficiently high strength at elevated temperatures. Without this condition it is impossible to operate a shaft kiln;

(b) Kiln diameter exceeding 3 m is inadvisable. Air distribution becomes irregular and results in unstable operation.

A common and effective kiln size is 180-200 t/d. Such a kiln would have an inside effective diameter of 2.4 m and a total height of approximately 8 m. Smaller kilns work even better because of improved air distribution inside the kiln's cross-section.

The vertical shaft kiln is simple in design. The upper part of the shaft (approximately 15-20% of the total height) is conical to correct for shrinkage of the nodules through drying, calcining and sintering.

The lower part is cylindrical and this part of the shaft serves as a collar and as a heat exchanger. The heat from the clinker preheats the moving air which flows counter-clockwise from the bottom of the cooler to the burning zone.

The raw mix and solid fuel fed to the kiln are agglomerated in a nodulizer in which is added 12-14% of water. Nodules of 1/2 inch in diameter (12 mm) are produced and are fed to the top of the kiln and distributed evenly over the surface by means of a rotating chute.

The feeding of the kiln is regulated according to the flue gas temperature, which should be kept at 80-90°C. The material flow should move downwards with a velocity of approximately 70 cm/s. Kilns are fitted at the bottom with grates of different designs. Clinker is discharged through either an hydraulically operated air-lock discharge gate or through another discharge system.

Combustion air is blown in counter-currents, and the pressure needed is about 1,200-2,000 mm water gauge (12-20 kPa); this is best obtained with a Roots blower.

Current air pollution regulations call for an electrostatic precipitator for the dedusting of the flue gas. Dust production of a shaft kiln is low, about 2% of the clinker production, but it looks worse because of the presence of evaporated water. The low temperature of flue gas makes it necessary to preheat the gas before the filter to about 90-100°C, which is the most suitable temperature for an electrostatic precipitator, i.e. 30-35°C above the dew-point of the kiln gases.

VIII. CONCLUSIONS

It is impossible to make recommendations which are applicable everywhere, however, it is hoped that these will be of use when the technology is examined for small-scale cement production in remote areas as well as in the least developed countries.

A. How to reduce capital investment

Total investment cost in percentage terms consists of the following:

Mechanical and electrical equipment	45-55
Civil works	25-30
Transport (C.I.F. - F.O.B.)	3-5
Installation	12-15
Miscellaneous	4-5

These figures indicate where savings can be achieved. Civil works form a high percentage of the costs. Considerable savings can be made here, for instance by reducing storage capacity. However, such savings depend to a large extent upon local conditions, and advice should be sought from an experienced consultant.

To reduce costs for the installation of mechanical and electrical equipment requires:

(a) A perfect lay-out;

(b) Programme evaluation;

(c) Intensive standardization;

(d) The site should be provided with a well-equipped workshop especially for steel-plate work and welding;

(e) Machinery manufacture and erection should be combined;

(f) All steel-plate work to a 25 mm thickness should be done at the site;

(g) The latest welding techniques should be applied;

(h) Considerable time can be saved by co-ordinating civil work with the installation of mechanical and electrical equipment.

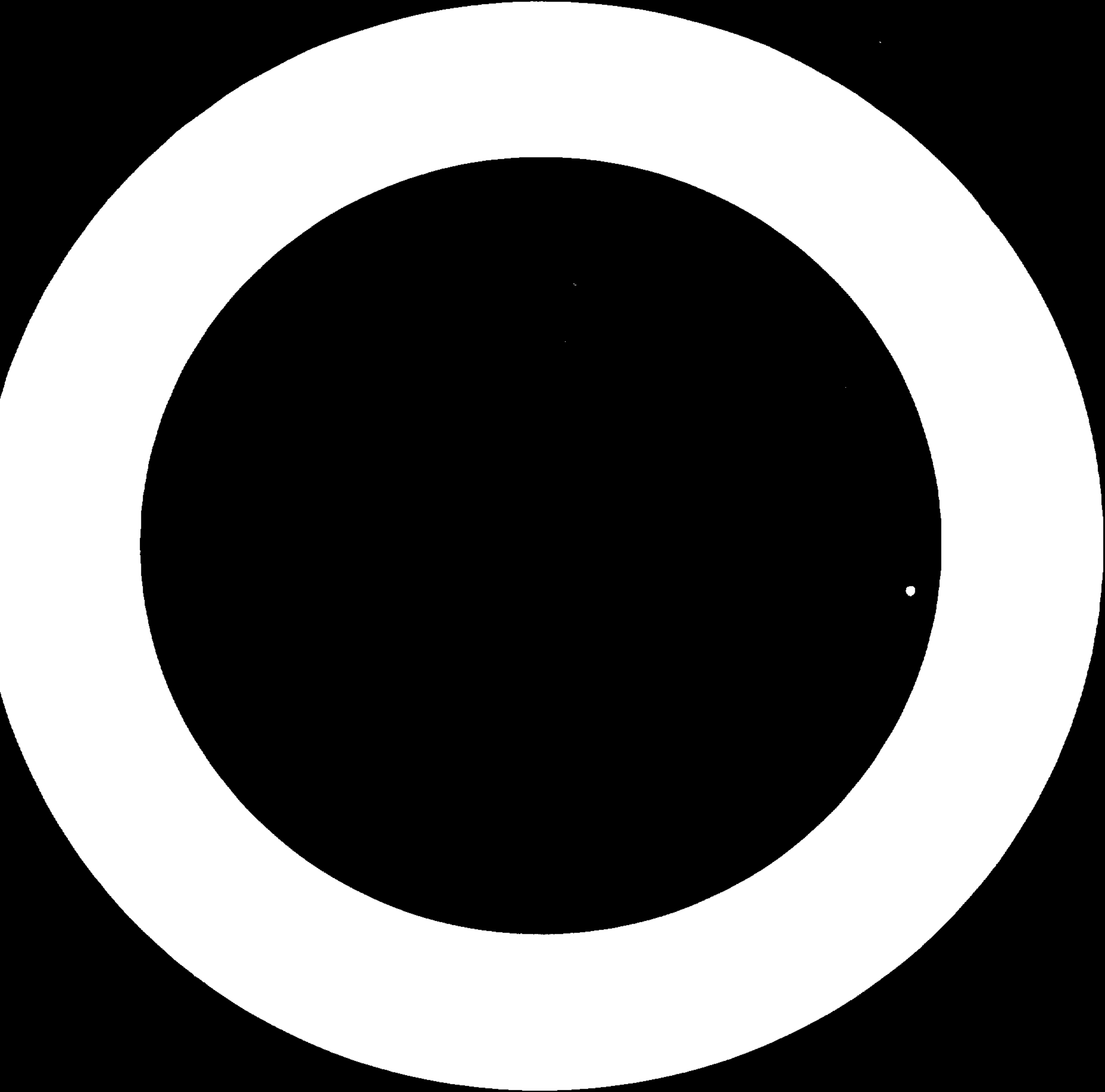
B. Implementation time

In a plant of 120,000 t/a capacity, civil works may involve about 8,000-10,000 m^3 of concrete and about 1,800 tons of mechanical and electrical equipment. The erection of civil works and the installation of mechanical and electrical equipment would involve approximately 120,000 and 140,000 work-hours respectively. A compact cement plant should not take more than 10 tc 13 months to erect on even extremely difficult sites.

C. Economic size

As indicated in annex I, shaft kiln plants producing 120,000-180,000 t/a would be the most economic size. For plants of larger capacities the rotary kiln technology would normally be recommended, especially of low volatile coal is not available. The availability of good plastic clay is also important to secure strong and heat-resistant nodules for the shaft kiln process.

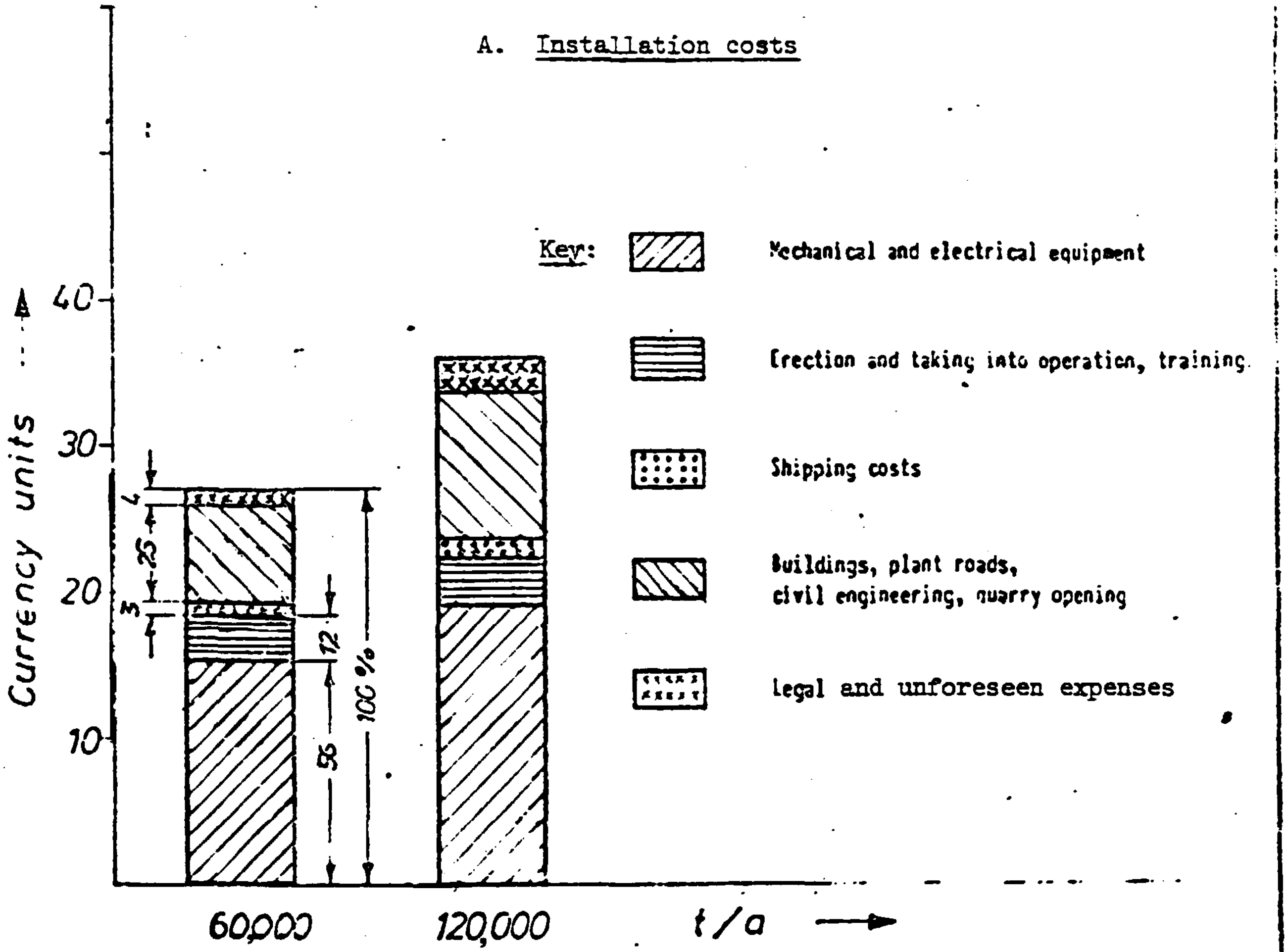
In order to give further information about the relatively unknown shaft kiln process, annex II provides a production record for the period 1972-1976 for a Kenyan shaft kiln, and annex III compares the cost of fuel and refractory consumption for shaft and rotary kilns at the same plant.



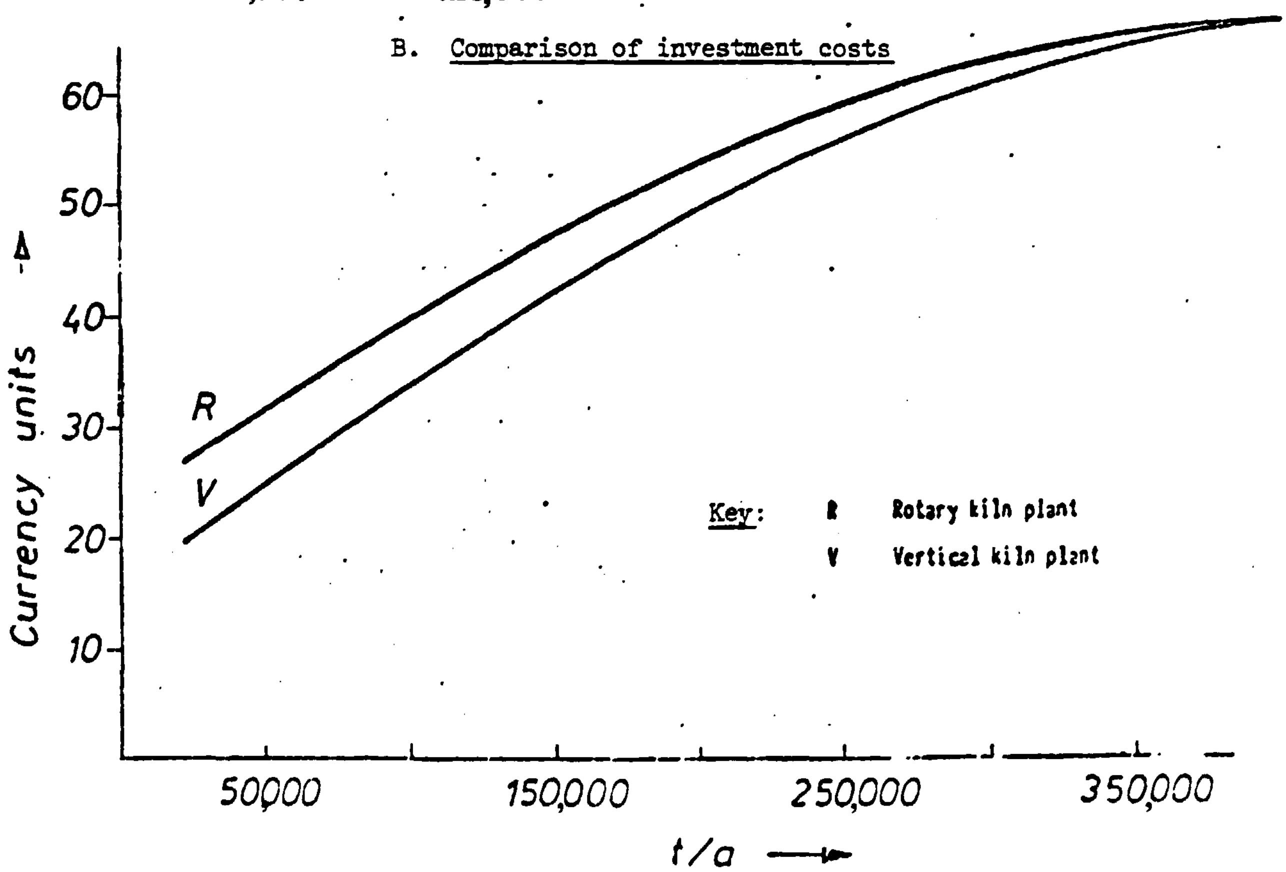
Annex I

COMPACT CEMENT PLANTS

A. Installation costs



B. Comparison of investment costs



Annex II

SHAFT KILN PERFORMANCE (1972-1976), BAMBURI PORTLAND CEMENT COMPANY LTD., KENYA

Month	1972 Production Rate (t/h)	1972 Energy Consumption kcal/kg	1972 Energy Consumption kWh/t	1973 Production Rate (t/h)	1973 Energy Consumption kcal/kg	1973 Energy Consumption kWh/t	1974 Production Rate (t/h)	1974 Energy Consumption kcal/kg	1974 Energy Consumption kWh/t	1975 Production Rate (t/h)	1975 Energy Consumption kcal/kg	1975 Energy Consumption kWh/t	1976 Production Rate (t/h)	1976 Energy Consumption kcal/kg	1976 Energy Consumption kWh/t
January	7.25	1 201		7.54	1 117		7.39	1 010		7.36	1 029		7.40	975	
February	6.75	1 173		7.37	1 110		7.26	1 004		7.24	698 a/		7.06	971	
March	7.41	1 189		7.50	1 126		7.1	1 052		7.13	975		7.09	957	
April	7.33	1 186		7.42	1 129		7.56	1 025		7.02	985		7.14	961	
May	7.23	1 188		7.56	1 100		7.25	1 044		6.97	987				
June	7.18	1 209		7.65	1 098		7.47	1 049		7.16	985				
Average	7.20	1 191	17.27	7.51	1 113	16.08	7.34	1 031	15.61	7.15	989	22.59			
July	7.36	1 174		7.45	1 098		7.30	1 058		7.25	995				
August	7.21	1181		7.34	1 112		7.25	1 049		7.22	981				
September	6.85	1 185		7.32	1 090		7.38	1 084		7.37	981				
October	6.91	1 182		7.54	1 084		7.14	1 084		6.77	991				
November	7.15	1 184		7.62	1 039		7.02	1 067		6.87	923				
December	7.35	1 186		7.38	995		7.06	1 047		7.22	968				
Average	7.15	1 182	15.39	7.44	1 068	14.63	7.15	1 084	18.27 b/	7.12	973				

a/ Drop in fuel consumption due to new type of fuel.

b/ Electrostatic precipitator installed.

Annex III

CUMULATIVE COSTS AT THE BAMBURI PORTLAND CEMENT COMPANY LTD., KENYA

A. Refractory costs
(US cents/ton clinker[a])

	Shaft kilns	Rotary kiln I
1973	32.8	240.9
1974	48.4	333.4
1975	52.5	254.7
1976 (to April)	3.1	365.1

Refractory price: approximately $325/ton.

B. Fuel costs
(Ksh/ton clinker[a])

	Shaft kilns (Coal)	Rotary kiln I (Fuel oil)
1973	21.69	11.27
1974	29.84	39.33
1975	37.50	48.11

a/ The monetary unit in Kenya is the Kenyan shilling (Ksh). At the time of the expert's visit in June 1976, the value of the shilling in relation to the United States dollar was $1 = Ksh 8.35.

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