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ASSISTANCE TO CONSOLIDATE AND DEVELOP THE BENGHAZI CEMENT FACTORY,

TF/LIB/75/002 .

LIBYAN ARAB JAMAHIRIYA.

Project findings and recommendations.

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

Based on the work of Aly Afify, cement industry adviser

id. 77-4749

Explanator ›tes

References to dollars ($) are to Un. 'tates dollars.

The monetary unit in the Libyan Arab ıiriya is the Libyan dinar (LD). During the period covered by the report, th· alue of the LD in relation to the United States dollar was $1 = LD 0.296.

A full stop (.) is used to indicate decimals.

A comma (,) is used to distinguish thousands and millions.

References to tons are to metric tons.

In tables, a dash indicates that the amount is nil or negligible.

Totals may not add precisely because of rounding.

Besides the common abbreviations, symbols and terms, the following have been used in this report:

Economic and technical abbreviations

A	ampere
AM	alumina modulus
ASTM	American Standards for Testing Materials
BSS	British Standard Specifications
c.i.f.	cost, insurance, freight
Kcal	kilocalorie
KV	kilovolt
KWh	kilowatt hour
LOI	loss of ignition
LSF	lime saturation factor
SR	silica ratio

Formulae

Al_2O_3	alumina
CaO	calcium oxide
Fe_2O_3	ferric oxide
K_2O	potassium oxide
MgO	magnesia
Na_2O	sodium oxide
SiO_2	silica
SO_3	sulphuric anhydride

Libyan company

LCC	Libyan Cement Company

Foreign companies

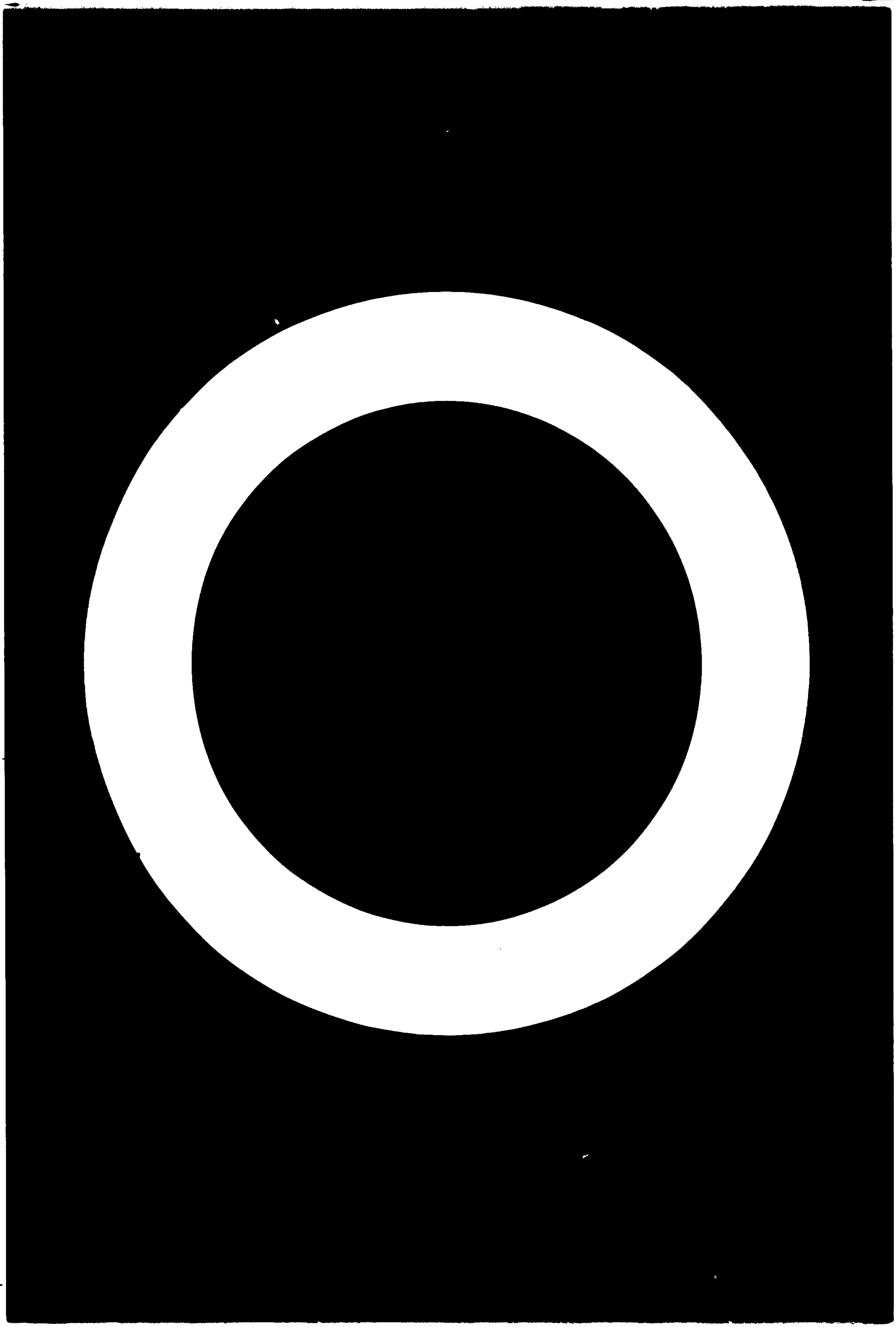
B and B	Bilfinger and Berger
CERIC	Centre d'étude et de réalisation industrielle et commerciale
IBICC	International Building Industrial and Commercial Contractor
KHD	Klöckner Humboldt Deutz

ABSTRACT

This report covers the second part of the one-year project in the Libyan Arab Jamahiriya "Assistance to consolidate and develop the Benghazi cement factory"(TF LIB/75/002). The first part was executed from February to April 1976 by a cement industry adviser assigned by the United Nations Industrial Development Organization (UNIDO); it is reported on in document UNIDO/IOD.37 of 24 May 1976. The expert returned to the country in November 1976 to complete the remaining nine months of his assignment. The project was undertaken at the request of the Government and financed under the UNIDO Trust Fund.

During the first three months of 1977, 160,503 tons of normal portland cement was produced at the Benghazi cement factory, representing 36% of the production target. The expert identified the causes of the shortfall and proposed corrective measures. He also assisted at the projects to construct the Hawari cement plant, a ceramic-bricks factory and a concrete-blocks plant, preparing organigrams for the required technical personnel and schedules for their employment. He made tests to determine the proper composition of the concrete to be used in the concrete-blocks plant and, for the plant being built at Souk-El-Knamis, worked out a raw-mix design for the cement that compensates for the high silica ratio of the raw materials. In addition, he assessed the available gypsum resources in the light of the cement industry's current and future needs and proposed a scheme for the opening of a new quarry.

The expert's findings were in each case accompanied by specific recommendations for action. More was accomplished under the project than had been planned, and work should now be continued with technical assistance in mechanical and electrical engineering. A team of four UNIDO experts was recommended.



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INTRODUCTION

The project "Assistance to consolidate and develop the Benghazi cement factory" (TF/LIB/75/002), requested by the Government of the Libyan Arab Jamahiriya, was approved by UNIDO in June 1975. The duration of the project was one year divided into two missions; the first was undertaken from February to April 1976 and the second from the middle of November 1976. The project was financed under the UNIDO Trust Fund at a cost of $49,000.

The Libyan Cement Company (LCC) built up the national cement industry in the eastern part of the country and has extended activities to cover various building-materials industries. The first cement rotary kiln was installed and started up in April 1972, with a yearly production capacity of 200,000 tons of normal portland cement. A second production line (600,000 tons/year) was started up in August 1974 and a third (again with a capacity of 600,000 tons/year) was put into operation in January 1977. Next, the project "Hawari" was established to construct a cement factory with an annual production capacity of 1 million tons, to be started up by the end of 1977. This will bring the total cement production in the Benghazi area to 2 million tons a year. (For a statistical review of clinker and cement production during 1975 and 1976, see annex I.)

To profit from the crushing plant of the Benghazi cement works, a lime plant was erected and put into operation in March 1975, with a capacity of 43,000 tons/year of hydrated lime. A second production line with the same capacity is planned. Paper bags for cement and lime are manufactured in a paper-bag factory which was started up in June 1975; the factory can produce 100,000 paper bags a day. In addition, a concrete-blocks factory is under construction, which is expected to be operational by November 1977 and to produce 100,000-120,000 m^3/year of finished concrete blocks. Finally, a ceramic-bricks factory with a capacity of 60,000 tons/year is being installed and will be ready to be put into operation by July 1977.

The country's industrial development has thus been progressing quite rapidly towards the realization of a well-defined building-materials complex. To meet the resulting need for technical personnel, a project involving training in cement technology was initiated, which may later be expanded to cover building materials and ceramics. UNIDO was requested to help consolidate the Benghazi cement works and to advise on developing the cement industry in general. The report of the adviser's first mission is contained in document UNIDO/IOD.37 of 24 May 1976. The adviser completed his second mission in June 1977. His duties were as follows:

(a) To supervise the production and engineering departments of the Benghazi cement factory and to co-ordinate and guide the work;

(b) To propose plans for production and maintenance and to approve and follow up executive programmes;

(c) To supervise development and simplification studies and to use their conclusions to solve problems;

(d) To propose specifications and standards for raw materials and equipment and ensure their application;

(e) To participate in the relevant committees in discussions of matters relating to the departments;

(f) To follow international research and developments in the cement industry and make the information available to staff in the local industry;

(g) To submit periodic reports on the work of the departments;

(h) To propose training requirements for local trainees to replace foreign technicians;

(i) To study projects referred to him by the LCC.

Under the last item, project activities were extended to cover consultancy work for: the Benghazi lime plant, the Benghazi paper-bags factory, the Hawari cement project, the Benghazi ceramics-bricks project, the Benghazi concrete-blocks project, the Souk-El-Khamis cement and lime works, and the Green Mountain cement project.

The names and functions of the project counterparts with whom the expert worked are given in annex II.

I. FINDINGS AND CONCLUSIONS

The Benghazi cement factory

The production targets set for 1977 were (a) for clinker, 59,500 tons a month or 714,000 tons for the year; and (b) for cement, 62,500 tons a month or 750,000 tons for the year (and the same amount of packed cement). Actual production during the first quarter of 1977 is indicated below:

	Clinker		Cement		Packed cement	
	Amount (tons)	% of target	Amount (tons)	% of target	Amount (tons)	% of target
January	54 494	91	61 468	98	58 140	93
February	38 386	64	46 638	75	52 462	84
March	40 747	68	52 397	84	47 951	77

The cumulative figures for the period are as follows:

	Clinker		Cement		Packed cement	
	Amount (tons)	% of target	Amount (tons)	% of target	Amount (tons)	% of target
To 31 January	54 494	91	61 468	98	58 140	93
To 28 February	92 880	78	108 106	86	110 602	88
To 31 March	133 627	75	160 503	86	158 553	84

Reasons for shortfall in production

By closely following performance at all stages during these three months and analysing the results, it was possible to identify the following causes of the production deficit:

(a) The excessive humidity of the clay owing to atmospheric conditions obstructed operations in the raw mills by causing clay rings to form and blocking feeding chutes. The problem was aggravated by the stoppage for overhauling of the auxiliary heat generator of raw mill 2. The required spare parts and lining fire-bricks have already been delivered, however, and the overhauling has been started;

(b) Frequent interruptions in kiln feeding have been caused by bucket elevators and raw-meal weigh-feeders. The suppliers Klöckner Humboldt Deutz (KHD) were requested to study the possibility of installing air lifts and weigh-feeders to back up the present system if necessary and thus eliminate such delays in production;

(c) Problems in the travelling-grates clinker coolers resulted from frequent damage to heat resistant plates. The management is experimenting with better-quality materials in an attempt to reduce such inconveniences. As the northern bearing of the clinker crusher of the third production line was often burnt, a new shaft was manufactured locally to replace the original one;

(d) Clinker bucket conveyors are often out of order owing to torsion or breakage of the buckets, and in some cases even the steel structure is distorted. Measures are being taken to correct such deficiencies in the third production line;

(e) The refractory lining in various parts of the heat exchanger, kiln exit hoods and clinker cooler has deteriorated. Although designed to last for more than ten years, the lining shows signs of abnormal wear. Complete sets have been ordered from abroad, some of which have already arrived, and the outlet hood of kiln 1 will be relined during the stoppage schedule for replacement of the kiln's middle tyre;

(f) The rubber belt conveyors used for clinker feeding of the cement mills are not capable of providing ample feed for continuous operation of cement mills 2 and 3, and consequently only one mill at a time can be run. Moreover, cement mill 1 is idle because of defects in its air compressor. A new compressor is on the way for pneumatic cement transport;

(g) Cement packing has been inefficient, owing mainly to blocked extraction outlets in the cement silos caused by excessive moisture in the compressed air. Arrangements have been made to replace the water cooling system of the compressors with an air air-cooler so as to avoid water leakage.

Production activities

Raw materials

The quarrying of raw materials proceeded at a satisfactory pace during March 1977. In the quarries, the drilling machines were operated for 145 hours with a drilling rate of 24 m/h, and 8,950 kg of explosives was used, with an average consumption of 157 g of explosives per ton of limestone. Both electrical shovel loaders were in operation for 449 hours, with a loading capacity of 199 tons/h. The units of heavy rolling stock were run for 1,597 hours. The consumption of gas-oil was 30,769 litres, amounting to an average of 0.340 litre per ton of handled raw material. The two limestone crushers were operated for 273 hours, crushing 56,900 tons of limestone and 2,080 tons of raw gypsum. The average crushing capacity was therefore 216 tons/h. Both clay crushers were run for 177 hours, crushing 28,400 tons of clay at an average crushing rate of 160 tons/h. The storage halls for raw materials were nearly always full because the rotary kilns frequently had to be stopped for relining and maintenance work. The process of sieving out the sized limestone dimensions for the lime plant is carried on parallel to the limestone crushing. Therefore the stoppages of the limestone crushers directly contributed to the lags in the lime-production schedule.

Raw grinding mills

Raw mill 1 was run for 381 hours; its output was 21,285 tons of raw-mix for an average of 55.8 tons/h. Stoppages were due to shut-downs of kiln 1; tripping of air compressor D 102; blockage of clay feed; repairs of the flap for the mill inlet and of the flap for discharge to raw-meal storage silo 1; and repairs of the limestone weigh-feeder and of the greasing device of the main driving gears.

Raw mill 2 was operated for 159 hours, producing 14,877 tons of raw-mix at an average rate of 93.9 tons/h. This reduced output was due to stoppage of the auxiliary heat generator, in that heating and drying during raw grinding is effected by the application of kiln exhaust gases. Mill stoppages were caused by stops of kiln 2 and by such factors as repairs on the rubber belts of the clay and limestone weigh-feeder and blocked clay chutes.

Raw mill 3 ran for 369 hours and produced 53,137 tons of raw-mix with an average production capacity of 144 tons/h. Mill shut-downs were due to stops of kiln 3; in addition, stoppages were caused by frequent tripping of the greasing device, damage to one of the bearings for the screw conveyor beneath the electrostatic precipitator, blockage of clay chutes and formation of clay rings owing to excessive moisture in the clay.

Rotary kilns

During March 1977, kiln 1 was operated for 562 hours, producing 11,659 tons of clinker for a thermal-consumption rate of 934 kcal per kg of clinker. The kiln was stopped during the period 24-28 March 1977 when the raw-meal distributor dropped from the second to the fourth stage. The stoppage was used for maintenance work on elevators K 134 and P 109 and on the travelling grates of the clinker cooler, and for replacing deformed buckets on clinker conveyor P 303. Short interruptions were caused by irregular performance of the weigh-feeder, breakdowns of the electrofilter exhaust fan and deformation of the buckets of clinker conveyors P 303 and P 110.

Kiln 2 was run for 225 hours; it produced 10,096 tons of clinker with an average thermal-consumption rate of 844 kcal per kg of clinker. The kiln was stopped during the period 6-18 March 1977 for repairing conveyor P 303 and for relining the kiln-exit nose-ring and outlet hood with refractory bricks. It was stopped again when part of a dip-pipe dropped in the fourth stage of the heat exchanger. The discharge of accumulated raw meal and the replacement of the damaged dip-pipe were accomplished on 29-31 March 1977. Other interruptions resulted from electrical failures in the travelling-grates motor for clinker cooler P 319 and from problems with the weigh-feeder.

Kiln 3 operated for 498 hours, producing 21,805 tons of clinker with a thermal-consumption rate of 894 kcal per kg of clinker. The kiln was stopped during the period 1-3 March 1977 for overhauling the weigh-feeder. It was stopped again from 5 to 7 March 1977 owing to damage to the northern bearing of the clinker crusher. Other interruptions were caused by deformed buckets on clinker conveyor P 407; a blocked clinker chute on drag chain P 411; irregularities in the weigh-feeder; a blocked second stage of the heat exchanger; a temperature rise in the clinker crushers; and tripping of the preheater gas ventilator.

Cement grinding mills

Cement mill 1 is still inoperative owing to a defective air compressor in the pneumatic cement-transport system.

Cement mill 2 ran for 334 hours to produce 23,279 tons of cement with an average output of 69.7 tons/h. Stoppages have been due mainly to defective clinker feeding from the clinker rubber belt conveyors, which are not capable of coping with the combined requirements of cement mills 2 and 3. Minor interruptions occurred because of frequent tripping of the greasing device, blockage of filter hoses as a consequence of a defective shaking device, blockage of chutes, tripping of the control voltage and damage to the coupling of bucket elevator Q 210.

Cement mill 3 was operated for 398 hours and produced 31,807 tons of cement with an average production capacity of 80 tons/h. Stoppages were due mainly to deficient clinker feed from the rubber belt conveyors. Interruptions were also caused by damage to the driving roller for clinker-feeding the weigh-belt; breakage of the coupling for rubber belt conveyor Q 207 and of the coupling of bucket elevator Q 210; tripping of the greasing device; blockage of filter hoses owing to the inefficiency of the shaking device; and blockage in the chutes.

Cement packing plant

Most of the difficulties in the cement packing plant have been due to blocked outlet chutes in the cement silos, which hindered the work of cement silos 2 and 4 (in addition to the problems of cement silos 1 and 3). The difficulties have been aggravated by lack of staff. The third production line is still suffering from frequent breaks in the coupling bolts for the hoist of the dispatch rubber belt and from the lack of drum motors.

Lime plant

During March 1977, the lime plant surpassed all production targets. The shaft kiln was operated for 602 hours, producing 2,584 tons of quicklime or 117% of the target, with a thermal consumption of 1,082 kcal per kg of lime. Output could have been even better if the amount of sized raw limestone had not been limited owing to stoppages of the cement rotary kilns. The lime hydrating unit was operated for 257 hours to produce 2,975 tons of slaked lime, 119% of the target, in spite of some stoppages caused by difficulties in finding marketing facilities. The lime packing plant was run 210 hours and packed 2,577 tons of slaked lime, 103% of the target. Occasional stoppages did not hinder the packing plant's performance. This picture shows that the lime factory is capable of continuous production at optimal rates if an adequate supply of raw stone can be maintained and marketing channels are well established.

Maintenance activities

Mechanical maintenance

The requirements for mechanical maintenance are increasing with the increasing age of the machinery. Maintenance is, however, impeded by the accumulated materials which obstruct movement and add to delays. The planning of preventive maintenance and of a procedure for ordering spare parts is still inadequate. As a preliminary step towards solving the problem, the suppliers recommended that experienced engineers collect the needed technical data. Nevertheless, maintenance difficulties can be expected to continue until the required mechanical engineers are employed. In addition, inconveniences are encountered in transporting spare parts and maintenance implements up to the heat-exchanger towers, where the lifts are out of order. The factory needs a mobile crane with a long telescopic stem. The maintenance section is trying to amelicrate the situation by organizing working orders, systematizing greasing and oiling procedures, training local personnel and holding regular co-ordination meetings for detecting eventual problems and deciding on the proper solutions.

The following mechanical-maintenance activities have been carried out:

(a) A general overhauling of the clinker conveyors, including those of the third production line;

(b) Replacement of the inlet plates for raw mill 1 and of the lining plates in raw mill 2;

(c) In raw mill 1, changing of the feeding hoppers of rubber belt conveyor C 104, the linkage between production lines 1 and 2, rubber belt conveyor 207 for clinker feeding and belt conveyor 212 of the lime plant;

(d) Maintenance of the bucket elevators: overhaul of elevator K 134 of kiln 1 and the packing glands for elevator U 146 of the packing plant;

(e) Substitution of segments for the outlet of kiln 2 and repairs of the sealing gland at the inlet;

(f) Erection of a distributor for the second stage of the heat exchanger of kiln 1;

(g) Overhaul of the clinker cooler of kiln 2, including substitution of defective grates and repair of the clinker drag-chain conveyor;

(h) Overhaul of the screw conveyor for cooling tower Q 104 of the first production line;

(i) Modifications of the flaps for clinker rubber belt conveyor 207, which feeds the cement mills, and installation of a new flap for clinker elevators 104 and 210;

(j) Overhaul of the mechanical filter of cement mill 2, replacement of the blocked filter bags in the filter of cement mill 3, changing of the V-belts of filter 2 and assembling of a motor for the dust filter of clinker conveyor Q 233 of the second production line;

(k) Overhaul of packing machine 4, including changing of the screw fins;

(l) Various maintenance work in the lime plant, including the overhaul of mechanical filter 527, the flap for kiln gases and the burner beam.

Electrical maintenance

The consumption of electrical power during March 1977 was 1,327,250 kWh for the first production line, 2,073,300 kWh for the second production line, 3,413,250 kWh for the third production line and 186,200 kWh for the lime plant, giving a total consumption of 7,000,500 kWh. The electrical current supplied by the General Electrical Corporation was interrupted several times by current failures and voltage drops, which caused appreciable production losses. There have also been several other problems. For example, layers of dust have accumulated on control contacts. It is proposed to employ a number of industrial-services personnel to keep the spilled materials cleared away. The high humidity level in the compressed air causes irregularities in the movement of raw meal over the weigh-belt feeder. It is recommended to provide the compressed-air system with air driers and the condensed water traps with automatic valves in order to drain out the accumulated water. Storage can be difficult owing to lack of space where cables and electrical parts can be reconditioned for further use. It is planned to reserve an open storage area for electrical parts within the scheduled warehouses.

Electrical-maintenance work has included replacement of: the main circuit breaker for the exhaust-gas ventilator of kiln 1, the circuit breakers for the air compressors of cement mill 2, the safety device for the oil pressure in the compressors of raw mill 1, the current transformers (30 kV, 300/5/5 A), the auxiliary circuit breakers for regulating the speed of the travelling grates of the clinker cooler of kiln 1, and the control and signalling instrumentation for water wells 1-4. In addition, the electrical circuits of the main drive motor of raw mill 2 were modified to protect the main motor in case of starter failure. Electrical feeding was accomplished for the gas-oil tanks of the kilns for the concrete-blocks project. The electrical cable feeding the ceramic-bricks project was protected with security pipes at crossing points. Moreover, studies were carried out on accomplishing: connection of the proposed emergency power generator to the Hawari cement project; permanent electrical feed for the electrical shovel loaders; a feeding cable for the training centre and for water well 6 in Wadi Gattara and the wells at the sites of the ceramic-brick and concrete-block installations; and reinforcement of the electrical feeders for workshops, new garages and warehouses. The General Electrical Corporation has been approached about providing permanent electrical feeders to the ceramic-bricks project and materials for the feeders of the Hawari cement project.

The Hawari cement project

The Hawari cement project is one of the largest undertakings in the recent industrial development of the Libyan Arab Jamahiriya. The contract (1/75) concluded with KHD on 18 January 1975 involves the construction of a cement factory with a yearly production capacity of 1 million tons of normal portland cement in a turnkey transaction of 271,447,443 marks (LD 32,619,339.225). The contractual period is 39 months, from 21 March 1975 (the date the contract came into force) to 20 March 1978 (the scheduled date of take-over, allowing three months for acceptance tests). Implementation has been proceeding according to schedule and is even a little in advance in some aspects. As to the civil construction side, the structural work is nearly finished and foundations are ready for erection activities. The remaining work in the civil field will be complementary. At the end of May 1977, the mechanical erection was half finished. It is therefore expected that the first no-load run will be possible by 10 August 1977, and a test run of the main machinery can be made on 1 November 1977. The approaching commissioning time calls for numerous preparatory measures, most important of which will be to ensure adequate solutions to the problems of the labour force and spare parts.

<u>Forecast of requirements for technical personnel</u>

The local technical staff should be ready to assume their duties by the beginning of the no-load run. To help with the employment of personnel, the UNIDO adviser prepared an organigram for the required staff (annex III), organized within disciplinary levels according to the official job scales, and a proposed schedule for the employment of personnel and of outside specialists under technical assistance arrangements (see annex IV). The local personnel has been subdivided into two groups:

(a) Staff to be employed immediately for jobs that require intensive training, i.e. in the Benghazi cement works and at the Hawari site, who will be sent to Souk-El-Khamis cement works to participate in a probationary period and to receive training from the contractor's commissioning staff;

(b) Staff to be employed gradually in the weeks before start-up. This group will receive on-the-job training from the Hawari commissioning staff, the staff delegated by the Benghazi cement works and their fellows employed earlier.

The technical assistance from outside specialists should comprise:

(a) The assistance stipulated in the contract with KHD, involving six specialists from th. suppliers for a period of two years;

(b) An additional group of 54 candidates, to fill the positions enumerated in the annex. It would be advantageous if this group could be employed through technical management contract agreements with a well-established firm, preferably with the suppliers so as to assure co-ordination with the contractual group;

(c) A team of four UNIDO experts:

A planning mechanical engineer for planning preventive maintenance and organizing a system for ensuring the availability of spare parts

A maintenance mechanical engineer for doing mechanical maintenance of cement machinery and equipment

A maintenance electrical engineer for maintaining the electrical equipment

An instrumentation electrical engineer for calibrating the measuring and control equipment and maintaining it

In addition, the UNIDO cement adviser could act as co-ordinator or team leader on site. The proposed duties of the team are given in the job descriptions in annex V.

The problem of spare parts

By the time the Hawari cement factory starts up, an adequate stock of spare parts should be available at site, to ensure continuous running and proper maintenance. Within the scope of contractual deliveries, spare parts have been provided for two years of normal operation. However, the suppliers submitted their detailed list of spare parts later than the date stipulated in the contract, and some 10,000 of the items included should be thoroughly reviewed. Moreover, the time factor has now become critical, since delivery of all the spare parts is not feasible by the starting-up date. The following procedure is therefore recommended:

(a) Parts of secondary importance (including durable items and items that can possibly be purchased or manufactured locally) should be eliminated from the list for the first two years. The remaining parts should be ordered as soon as possible, stressing the need for urgent delivery;

(b) Based on present price levels, the projected magnitude of prices should be discussed, at least for such standard parts as ball-bearings, V-belts, rubber belts, electrical motors, aerating and filtering cloth, wire ropes and normal steel products and sections;

(c) The savings effected through (a) and (b) could be invested in parts that are specially sensitive. Such parts should be carefully determined, through ample study. As this would take some time, it should not be allowed to prejudice the immediate ordering of the parts mentioned in (a) above. The additional sensitive parts will form a supplementary list, still to be ordered as part of the contractual obligation concerning spare parts;

(d) The supplier should establish a new spare-parts list comprising the first order (a) and second order (c), including comprehensive technical specifications, reference part numbers according to suppliers' codes and dimensions wherever possible. It has been noted that the present list gives similar nomenclature for parts of different weights and prices, which thus cannot be distinguished for proper storage organization or rational application. (The adviser has already helped to clarify references in a number of instances.) The preparation of a new list need not delay the order for spare parts, which may be submitted on the basis of the present list, but the rectified document should be available before the parts are delivered so that it can be used by store and maintenance personnel to simplify handling;

(e) Eventually, a protocol should be drawn up with the suppliers emphasizing the above steps and affirming their contractual responsibilities in relation to the supply of spare parts for two years of normal operation. It must be remembered that missing spares can draw one or more production units to a complete standstill, causing shortfalls in production and losses in revenue. The necessary precautions should therefore be taken, and the protocol formulated roughly as follows:

According to contractual stipulations, the supplier guarantees that the spare parts will be sufficient for the said period of two years of normal operation. In case the quantities or types of spare parts are not sufficient for this period, the supplier will be obliged to deliver free of charge, c.i.f. Benghazi port, any quantities and types of spare parts so found to be needed. For the purpose of determining fulfilment of the original obligation, representatives of both parties will recalculate the spare parts needed for the said two years of normal operation two months before the expiration of the guarantee period. The said recalculation will be made on the basis of the quantities and types of spare parts actually consumed during the actual working hours of the period of ten months of normal operation of the plant. It is understood that recalculation of the requirements for spare parts will take into account factors such as machine age and the experience of the people in the plant. The quantities and types of spare parts so calculated will be taken as a basis for readjusting the quantities of lacking spare parts, which will be delivered by the supplier c.i.f. Benghazi port, free of charge.

Review of gypsum reserves

The present stage of cement-industry development calls for a general review of the raw-gypsum resources available for cement production. Ample reserves should be assured to meet the requirements of the existing factory, the Hawari factory and the cement facility planned for the Derna region. Gypsum quarrying has been affected by the following factors:

(a) Rajma 1 quarry (in the vicinity of Rajma village). The public committee of Rajma asked that all quarrying activities be stopped because the inhabitants of the neighbourhood were being disturbed by the blasting noise. Efforts to resume quarrying failed and work is at a complete standstill. This quarry represents the best source of gypsum, since the gypsum is superior in quality, economically exploitable and near the site of the factories;

(b) Rajma 2 quarry (near the military territories). The traffic in gypsum lorries was interrupted when the original road to the quarry was condemned. A new access road, paved with crushed limestone and provided with drain-pipes, was built at a cost of LD 7,000;

(c) Hawa-El-Barag quarry. This quarry should be worked in the summer-time because in the winter-time the rain-water accumulates in the quarry pit. In general, the following difficulties may be encountered:

(i) The high-tension electrical line that is only 250 m from the quarry front obstructs quarrying activities in that direction, which is, however, the location of the most abundant gypsum formation. Representatives of the General Electrical Corporation have warned that blasting should be at least 1 km from the line;

(ii) A number of caves are unevenly distributed among the gypsum strata. Some of them may occur as deep as 10 m, which represents a considerable danger to the security of personnel and equipment;

(iii) Agricultural activities may obstruct gypsum and overburden storage and use of the quarry access road;

(iv) The gypsum is covered by thick strata of clay and limestone (up to 17 m in some areas), making exploitation less economic;

The best offer for opening the quarry was LD 196,990, which is already a high expenditure in addition to the continuing cost of removing the clay and limestone overburden. In spite of the aforementioned difficulties, however, Hawa-El-Barag quarry should be exploited because of the scarcity of gypsum reserves available for cement manufacture. A proposal for opening the quarry is given in annex VI;

(d) El-Gara gypsum deposit. Next to the above, the nearest gypsum deposit is located in El-Gara. The situation there is not satisfactory, for the gypsum is at an unworkable level. The site is about 60 m from the factory across an unpaved road in a desert area. Furthermore, there are only 56,200 tons of gypsum, which would meet cement requirements for barely six months (taking into account full production capacity after the commissioning of the Hawari cement project, i.e. 2 million tons/year of cement requiring 120,000 tons of gypsum).

The following steps are proposed:

(a) The Hawa-El-Barag deposits should be opened to serve as a stand-by for the Rajma quarries. The former can be exploited during the dry season and the latter during the rainy season. The two sites together will be adequate until new gypsum resources are assured;

(b) At the same time, geological research should be undertaken to uncover additional gypsum deposits that may exist in the Rajma-Ebiar area. The excavation work done in connection with roadbuilding in the region indicated the presence of additional gypsum;

(c) The latest geological investigations in the Sedra area should be studied, since this area may be able to meet future gypsum requirements for some time.

(d) Gypsum should be transported on an experimental basis from the western deposits if these are confirmed by the recent investigations. After the economics of exploitation and transport are worked out, it would be advantageous to depend mainly on the western resources and to keep the near-by gypsum deposits as a safeguard, should the supply of gypsum from the west be interrupted for any reason.

The concrete-blocks project

The project was originally entrusted by the General National Organization for Industrialization to the American firm Interkiln as general contractor. The plant was designed to produce 100,000-120,000 m^3 a year of finished concrete blocks. The guaranteed minimum capacity can be expressed in an equivalent net production as 6,200,000 standard concrete non-load-bearing blocks a year (ASTM No. C129) or 4,665,600 load-bearing blocks (ASTM No. C90-70). When Interkiln gave up the project, supervision was taken over by LCC, and the Swiss firm Prospective Engineering Gestion (PEG) has undertaken to complete the engineering work and provide missing items. The civil construction was entrusted to the German firm Bilfinger and Berger (B and B), and the mechanical and electrical aspects of erection to the Greek firm International Building Industrial and Commercial Contractor (IBICC). B and B has already handed over the first part of the aggregate crushing plant and is about to finish the plant for concrete-block production. IBICC has just started activities, which, by contractual agreement, should be finished by 21 November 1977.

The present situation calls for immediate initiation of the first stage in opening the quarry. The second stage will take place before commissioning.

All essentials, including an organigram for technical personnel (annex VII) and an employment proposal (annex VIII), were prepared by the UNIDO adviser. From the national labour force 10 individuals are urgently required for the first stage of activities. Quality-control personnel can be trained locally at the LCC laboratories for following up the quarry opening process. The second stage involves gradually employing 34 local individuals up to the date of commissioning, with priority to maintenance personnel so that they can obtain preliminary training throughout the erection proceedings. Furthermore, 10 specialists could be contracted from an industrial firm for assuring satisfactory operation and the utilization of national skills.

As far as organization is concerned, it would be advantageous if the ceramic-bricks factory and the concrete-blocks plant could be integrated into a sister enterprise in the building-materials industries. Aside from administrative advantages, this procedure would enable both projects to profit from the exemptions provided for in the national regulations to newly developing industries during their early stages of operation.

Laboratory studies on a concrete-mix design

The previous drilling investigations indicated that the most suitable aggregate resources were in Magzaha (Gasr Guheish), where the aggregate crushing plant has been located. The top strata in the area are composed of hard limestone which can be obtained from secondary blast rocks usually brownish in colour, whereas deeper quarrying would reveal soft limestone which is characterized by a white, chalky appearance.

For defining the proper proportions of the concrete composition and determining the optimum percentages of the various constituents, a test programme was proposed by the adviser, with the following objectives:

(a) To determine the compressive strength of the aggregate, mixed to the proportions specified by the block-machine suppliers;

(b) To determine the optimum amount of sand or at least acceptable sand proportions;

(c) Using actual block well water, to determine if any reaction occurs.

The adviser organized the tests at the LCC laboratories and supervised their execution.

Description of samples used

Test samples were prepared as follows: samples of hard and soft limestone were obtained from the quarry area, from the quarry front and from the stock-piles of the old quarry. Each sample was crushed through the laboratory jaw-crusher to a maximum size of 10 mm. Each crushed product was homogenized and passed through laboratory sieves to be separated into fractions of seven sizes:

Millimetres
0 - 0.150
0.150 - 0.297
0.297 - 0.590
0.590 - 1.180
1.180 - 2.380
2.380 - 4.760
4.760 - 9.520

The resulting fractions were oven dried before use.

The beach sand came from the sand dunes at Geminis beach, which is being quarried for building sand. The sample was dehydrated and the granulometric features were tested (see annex IX).

The cement sample was taken in two freshly packed cement bags from the LCC packing plant. Physical tests were made to ensure that the cement fulfilled BSS requirements (see annex X). For each test 400 g of cement was weighed out, amounting to about 9% of the aggregate weight. Cement was taken from only one cement bag, the other being kept for reference. Average samples of cement, sand and aggregate were chemically analysed (annex XI).

The water used was obtained from the concrete-block plant's source, i.e. the Saadawyia well (the adviser's analysis is shown in annex XII). For each test 500 g was used as gauging water, equivalent to 10.2% of the total dry weight.

Experimental procedure

A series of tests was performed in accordance with the planned proportions. Aggregate, sand and cement were weighed out for each test, up to 4,500 g total, dry mixed for two minutes, then mixed for five minutes with the gauging water. Concrete paste was moulded and vibrated for one minute using BSS moulds and vibrating machines. Three specimens were prepared for each crushing test. The specimens were then labelled and cured in fresh water for 21 days and at room temperature for 7 days. Next, crushing tests were made with a compression machine after the crushing surfaces had been capped with a thin levelling layer of cement paste.

Test results

.he characteristics of the concrete mixes tested for the concrete-blocks project are shown in annex XIII. The tests were divided into three series:

Series A

Three separate tests were performed to determine the most suitable concrete-block composition of aggregate of hard, soft or average stones, without beach sand. The results confirmed the superiority of hard stone, which attained a compressive strength of 90 kg/cm^2 after 7 days and 137 kg/cm^2 after 28 days.

Series B

Tests were performed on concrete mixtures with various combinations of beach sand and limestone fines to determine whether crushing dust could be substituted for beach sand. The results showed that a proportion of 15% beach sand would give reasonable compressive strength (103 and 168 kg/cm^2 after 7 and 28 days). With more beach sand the compressive strength deteriorated, apparently owing to the high water-absorption power of the sand.

Series C

The tests of series B were repeated using a higher fineness modulus which allowed the percentage of beach sand to be reduced on account of the fine fractions of the aggregate components. This approach would be economically favourable, since part of the relatively costly beach sand is replaced by fine fractions of crushed limestone. The test results revealed comparatively higher strength with the fineness modulus increased from 3.7 to 3.9 and the sand component reduced from 15% to 6%; the compression resistance of the test cubes attained 119 kg/cm^2 after 7 days and 174 kg/cm^2 after 28 days.

Conclusions

From this series of tests, it can be concluded that the hard limestone gives stronger aggregate resistance with better concrete compressive strength. Nevertheless, satisfactory results can be obtained with a mixture of hard and soft limestone aggregate provided that sand is added. A higher fineness modulus makes it possible to reduce the percentage of sand, thus obtaining better compressive strength at less cost. The composition can be more precisely determined by analysing the production process and quality-control data.

The ceramic-bricks project

The installation of the ceramic-bricks plant was entrusted to the French firm Centre d'étude et de réalisation industrielle et commerciale (CERIC) on 13 February 1973 on a turnkey basis for a plant producing 60,000 tons/year of ceramic-clay bricks. The project value was LD 1,430,373 comprising the study of raw clays; civil construction; supply of mechanical and electrical machinery and equipment, materials accessories and spare parts for two years' operation at maximum output; erection; start-up; take-over tests; and management assistance.

A time schedule was concluded for completion of the entire plant within 30 months of the date of the contract coming into force. Execution has been delayed owing to some unforeseen circumstances. However, the plant is expected to be ready for the probationary period with no-load running by the end of June 1977.

The commissioning time is so near that immediate steps have to be taken to employ technical personnel so that they can be ready to assume their responsibilities when the no-load run is made. The UNIDO adviser prepared an organigram for this purpose (annex XIV) showing job scales, administrative levels and the relations between posts. He also developed a proposal for employment (annex XV) comprising:

(a) Technical assistance (four specialists) to be provided by CERIC under the contract during the first year of operation after the provisional take-over of the plant;

(b) Positions that can be filled from the local labour force. It is strongly recommended that such staff be employed as early as possible so that they can work with the CERIC experts during start-up;

(c) Specialized assistance during the first year of operation, preferably to be provided through arrangement with a highly regarded firm in ceramics manufacturing.

The Souk-El-Khamis cement project

The Polish consultancy firm, Polservice, is proceeding with detailed geological investigations in the quarry area. The pits being drilled, trenched and dug should yield sufficient raw materials for at least 50 years' consumption at the present installed production capacity of the plant (1 million tons a year of normal portland cement). The investigations have revealed that the composition of limestone in the area varies from one spot to another, and the exploitation of the limestone quarry requires careful selective quarrying to avoid any of the dolomitic stone, which is plentifully intercalated into the limestone strata in some places.

The chemical composition of the limestone from the area investigated and of the clay from the Bu-Gheilan quarries showed a silica ratio higher than the recommended level. This feature would necessitate more intensive burning, causing higher calorific consumption and excessive wear of the refractory lining of the rotary kilns. The high silica content also tends to reduce the clinker coating in the burning zone and consequently shortens the lifetime of the exposed fire-bricks. To avoid such effects, the raw-mix composition would have to be corrected by adding ferric oxide and alumina (using iron ore and bauxite) so as to reduce the silica ratio. As Polservice cannot procure the bauxite in the short time alloted for putting the plant into operation, the UNIDO adviser proposed a corrected raw-mix design based on only iron ore as an additive, using 81% limestone, 17.1% clay, and 1.9% iron ore (see annex XVI). The resulting clinker has a lime saturation factor of 0.93 and an alumina modulus of 1.[illegible], in full compliance with BSS. The compounds content is also reasonable.

II. RECOMMENDATIONS

Based on his experience, the adviser recommended the following measures, some of which have already been described in connection with the relevant findings:

1. The imminent commissioning dates of the Hawari project, the ceramic-bricks factory and the concrete-blocks plant call for immediate action to secure the required personnel by the time no-load runs of machinery and equipment are made. Technical staff should therefore be employed according to the schedules prepared by the adviser. Furthermore, it would be advisable to reinforce this staff with a team of UNIDO experts. Detailed proposals are given in the annexes.

2. Ample resources of gypsum should be assured to cope with the requirements of the existing cement factory, the Hawari project and the planned cement project in the Derna region. As elaborated in the chapter "Review of gypsum reserves", the necessary steps are (a) exploitation of the Hawa-El-Barag gypsum quarry (see also annex VI); (b) complementary geological research to find additional gypsum deposits; (c) study of the latest investigations in the Sedra area; and (d) transport of gypsum on an experimental basis from the western gypsum deposits.

3. Details of preventive maintenance should be tabulated in a simplified, comprehensive schedule. A team of maintenance personnel with well-defined responsibilities should be selected for each group of machinery. Such staff would be entrusted with timing periodic inspections, reviews, checking, routine maintenance and general overhauling, and with keeping special records for man-hours per operation and the average lifetime of parts.

4. The provision of spare parts should be rationalized with a system of automatic ordering in accordance with ordering and minimum-stocks data. It would be advisable to issue a general order at the beginning of each financial year, taking advantage of the inventory at the year's end. Another, smaller order could be made during the year if excessive wear reduced the stock of a particular item. A precise register should be kept to follow up each order through receipt of the part, review and quality control.

5. By the time the Hawari cement factory starts up, an adequate stock of spare parts should be available on site so as to ensure continuous running and proper maintenance. The ordering of certain spare parts of secondary importance should be postponed during the first two years of operation in favour of stocking parts that are specially sensitive. A new spare-parts list should be developed with comprehensive technical specifications, reference part numbers according to supplier's codes and dimensions wherever possible. The adviser's detailed recommendations for the ordering of spare parts and the preparation of a new list are given on pages 16 - 17.

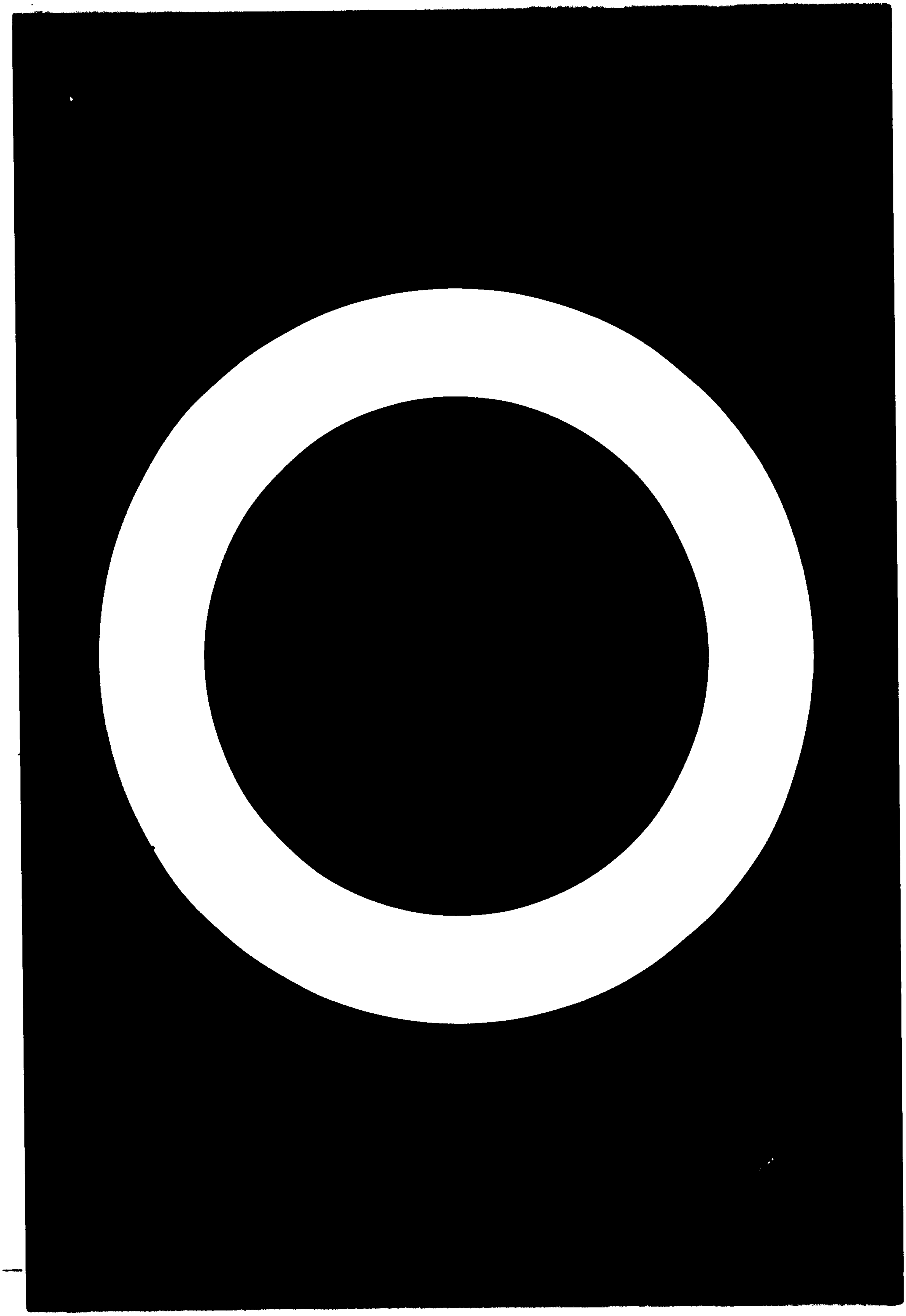
6. To support the aspects of the project related to training and managerial development, LCC might make use of technical training aids, industrial information services, research and documentary facilities provided by UNIDO.

7. The quality of the concrete in the concrete-blocks plant will be satisfactory if a mixture of hard and soft Magzaha limestone is used, provided that the proper amount of sand is added. This procedure will make the block production more economic. It is therefore advisable to procure a sand concession; chemical and physical testing should be carried out before an agreement is entered into.

8. To reduce the deficits in production caused by the frequent interruptions in kiln feed, a stand-by device for raw-mix manipulation and feeding should be introduced and the first bucket conveyor extended to serve in an emergency for removal of clinker from kiln 3.

9. Since the lifetime of the lining plates of raw cement mills is short and damage to the heat-resistant travelling grates of the clinker coolers is frequent, it is worthwhile to purchase plates of superior quality. The comparatively higher price will be compensated for by easier maintenance and continuous production.

10. The high humidity level in the compressed air causes a lot of difficulties. In addition to replacing the water-coolers with air air-coolers, the management should provide the compressed-air system with air-drying facilities and the traps for condensing water with automatic valves to drain out the accumulated water.



Annex I

STATISTICAL REVIEW OF CLINKER AND CEMENT PRODUCTION DURING 1975 AND 1976

Month	Clinker				Cement			
	Monthly		Cumulative		Monthly		Cumulative	
	Amount (tons)	Fraction of capacity a/ (%)	Amount (tons)	Fraction of capacity (%)	Amount (tons)	Fraction of capacity b/ (%)	Amount (tons)	Fraction of capacity (%)
1975								
January	35 662	71.3	35 662	71.3	35 835	68.2	35 835	68.2
February	22 823	45.6	58 485	58.4	38 643	73.6	74 478	70.9
March	30 280	60.5	88 765	59.1	39 338	74.9	113 816	72.2
April	41 201	82.4	129 966	64.9	51 033	97.2	164 849	78.5
May	27 573	55.0	157 539	63.0	34 157	65.0	199 006	75.8
June	40 090	80.2	197 629	65.9	31 975	60.9	230 981	73.3
July	43 578	87.1	241 207	68.9	44 287	84.3	275 268	74.9
August	38 446	76.9	279 653	69.9	35 125	66.9	310 393	73.9
September	36 163	72.3	315 816	70.2	37 444	71.3	347 837	73.6
October	39 504	79.0	355 320	71.0	33 998	64.7	381 835	72.7
November	32 005	64.0	387 326	70.4	45 945	87.5	427 780	74.0
December	51 202	102.4	438 528	73.0	37 786	72.0	465 566	73.9
1976								
January	42 098	84.2	42 098	84.2	47 863	91.2	47 863	91.2
February	33 159	66.3	75 257	75.3	43 037	82.0	90 900	86.6
March	41 009	82.0	116.266	77.5	48 698	92.8	139 598	88.6
April	30 074	60.1	146 340	73.2	26 042	49.6	165 640	78.9
May	28 730	57.5	175 070	70.0	48 842	93.0	214 482	81.7
June	26 799	53.6	201 869	67.2	30 808	58.7	245 290	77.9
July	30 662	61.3	232 531	66.4	16 519	31.5	261 809	71.3
August	39 279	78.5	271 810	67.9	35 912	68.4	297 721	70.9
September	10 100	20.2	281 910	62.6	21 194	40.4	318 915	67.5
October	41 781	83.6	323 691	64.7	35 612	67.8	354 527	67.5
November	36 742	73.5	360 433	65.5	36 352	69.2	390 879	67.7
December	43 939	87.9	404 372	67.4	41 100	78.3	431 979	68.6

a/ Capacity = 50,000 tons/month

b/ [illegible]

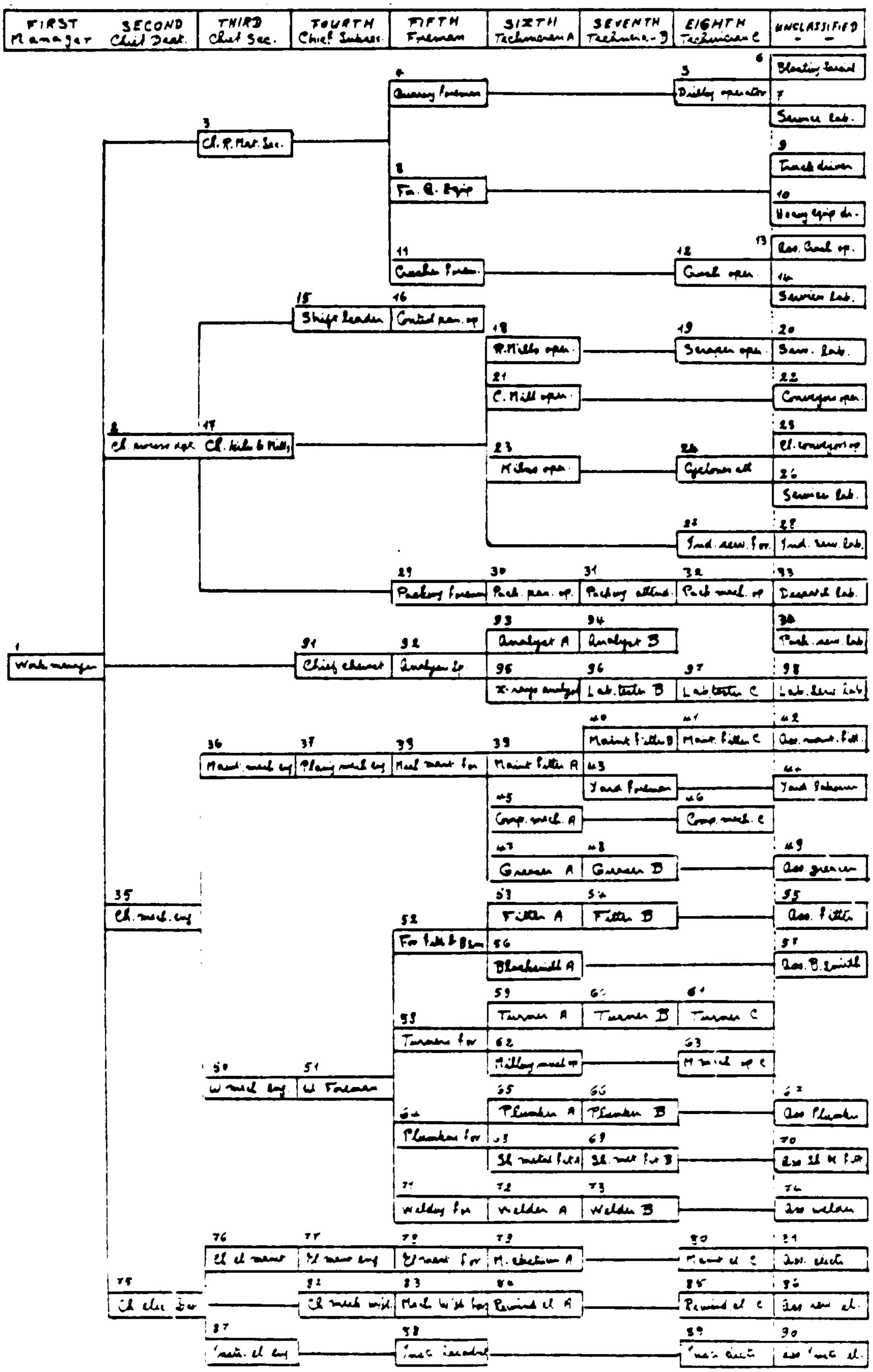
Annex II

NAMES AND FUNCTIONS OF PROJECT COUNTERPARTS

H. Najib Lathram	Chairman
A. M. El-Gheriani	General director
M. El-Naihoum	Financial manager
A. K. Mukraz	Administrative manager
I. El-Degawi	Commercial manager
R. Lotfy	Management and training adviser
S. Awad	Financial adviser
A. Hakam G. El-Din	Legal adviser
A. Latif Gomaa	Chief, project section
A. Fathi	Chief, raw material laboratory and packing
A. Bakr El Saltany	Chief, process department
E. Shehata	Chief, mechanical department
H. Faitouri	Chief, mechanical maintenance section
M. Tueima	Chief, mechanical workshop section
S. Hikal	Chief, electrical department
M. Eleyan	Electrical maintenance engineer
M. Ben Zablah	Chief, quarries section
S. Bekhit	Chief, crushing section
S. Mohamed	Laboratory chemist
I. El Fallah	Chief, kilns section
S. Masoud	Chief, mills unit
M. Gamal Azouz	Chief, packing section
W. Abd-El-Samad	Chief, lime plant
B. A. El-Talhi	Chief, purchase section
G. Gamal El Din	Chief, stores section
F. El-Dilih	Chief, transport section

Annex III

PROPOSED ORGANIGRAM FOR HAWARI
TECHNICAL PERSONNEL



Annex IV

PROPOSED SCHEDULE FOR EMPLOYMENT OF HAWARI TECHNICAL PERSONNEL

Job No.	Position	Local personnel to be employed:		Outside specialists		UNIDO tech. assist.	Total
		Immed-iately	Before start-up	KHD contract	Manage-ment contract		
1	Plant manager	1	-	-	-	-	1
2	Chief, process department	-	-	1	-	-	1
3	Chief, raw materials section	-	-	1	-	-	1
4	Quarry foreman	-	1	-	-	-	1
5	Drilling operator	-	2	-	-	-	2
6	Blasting specialist	-	2	-	-	-	2
7	Service labourer	-	6	-	-	-	6
8	Foreman, quarry equipment	-	1	-	-	-	1
9	Truck driver	-	10	-	-	-	10
10	Heavy equipment driver	-	15	-	-	-	15
11	Crushers foreman	1	-	-	-	-	1
12	Crushers operator	2	-	-	-	-	2
13	Assistant crushers operator	-	2	-	-	-	2
14	Service labourer	-	8	-	-	-	8
15	Shift leader	-	-	-	4	-	4
16	Control panel operator	2	-	-	6	-	8
17	Chief, kilns and mills	1	-	-	-	-	1
18	Raw mills operator	2	-	-	2	-	4
19	Scraper operator	-	7	-	-	-	7
20	Services labourer	-	8	-	-	-	8
21	Cement mills operator	2	-	-	2	-	4
22	Conveyors operator	-	4	-	-	-	4
23	Kilns operator	-	-	-	4	-	4
24	Cyclones attendant	-	8	-	-	-	8
25	Clinker conveyor operator	-	4	-	-	-	4
26	Services labourer	-	2	-	-	-	2
27	Industrial services foreman	-	1	-	-	-	1

Job No.	Position	Local personnel to be employed: Immed-iately	Before start-up	Outside specialists KHD contract	Manage-ment contract	UNIDO tech. assist.	Total
28.	Industrial services labourer	-	8	-	-	-	8
29	Packing foreman	1	-	-	-	-	1
30	Packing panel operator	2	2	-	-	-	4
31	Packing attendant	-	4	-	-	-	4
32	Packing machine operator	-	16	-	-	-	16
33	Dispatch labourer	-	12	-	-	-	12
34	Packing services labourer	-	6	-	-	-	6
35	Chief mechanical engineer	-	-	1	-	-	1
36	Maintenance mechanical engineer	-	-	-	-	1	1
37	Planning mechanical engineer	-	-	-	-	1	1
38	Mechanical maintenance foreman	-	-	-	3	-	3
39	Maintenance fitter A	7	-	-	5	-	12
40	Maintenance fitter B	-	8	-	2	-	10
41	Maintenance fitter C	4	3	-	3	-	10
42	Assistant maintenance fitter	-	10	-	-	-	10
43	Yard foreman	-	1	-	-	-	1
44	Yard labourer	-	6	-	-	-	6
45	Compressor mechanic A	-	-	-	1	-	1
46	Compressor mechanic C	2	-	-	-	-	2
47	Greaser A	1	-	-	-	-	1
48	Greaser B	2	2	-	-	-	4
49	Assistant greaser	-	4	-	-	-	4
50	Workshop mechanical engineer	-	-	1	-	-	1
51	Workshop foreman	-	-	-	1	-	1
52	Foreman, fitters and blacksmiths	-	-	-	1	-	1
53	Fitter A	1	-	-	1	-	2
54	Fitter B	2	-	-	-	-	2
55	Assistant fitter	-	4	-	-	-	4

Job No.	Position	Local personnel to be employed: Immed-iately	Before start-up	Outside specialists KHD contract	Manage-ment contract	UNIDO tech. assist.	Total
56	Blacksmith A	-	1	-	-	-	1
57	Assistant blacksmith	-	1	-	-	-	1
58	Turners foreman	-	-	-	1	-	1
59	Turner A	2	-	-	-	-	2
60	Turner B	1	2	-	-	-	3
61	Turner C	-	2	-	-	-	2
62	Milling machine operator A	-	-	-	1	-	1
63	Milling machine operator C	-	1	-	-	-	1
64	Plumbers foreman	-	-	-	1	-	1
65	Plumber A	1	-	-	1	-	2
66	Plumber B	-	2	-	-	-	2
67	Assistant plumber	-	4	-	-	-	4
68	Sheet-metal fitter A	1	-	-	1	-	2
69	Sheet-metal fitter B	-	2	-	-	-	2
70	Assistant sheet-metal fitter	-	4	-	-	-	4
71	Welding foreman	-	-	-	1	-	1
72	Welder A	3	3	-	-	-	6
73	Welder B	-	5	-	-	-	5
74	Assistant welder	-	5	-	-	-	5
75	Chief, electrical department	-	-	1	-	-	1
76	Chief, electrical maintenance	1	-	-	-	-	1
77	Electrical maintenance engineer	-	-	-	-	1	1
78	Foreman, electrical maintenance	1	-	-	-	-	1
79	Maintenance electrician A	-	-	-	8	-	8
80	Maintenance electrician B	8	-	-	-	-	8
81	Assistant electrician	-	4	-	-	-	4
82	Chief, mechanical workshop	1	-	-	-	-	1
83	Foreman, mechanical workshop	1	-	-	-	-	1
84	Rewinding electrician A	-	-	-	1	-	1

Job No.	Position	Local personnel to be employed: Immed-iately	Local personnel to be employed: Before start-up	Outside specialists: KHD contract	Outside specialists: Manage-ment contract	UNIDO tech. assist.	Total
85	Rewinding electri-cian C	1	1	-	-	-	2
86	Assistant rewinding electrician	-	1	-	-	-	1
87	Installation electri-cal engineer	-	-	-	-	1	1
88	Installation specialist	-	-	1	3	-	4
89	Installation electrician	3	4	-	-	-	7
90	Assistant installation electrician	-	4	-	-	-	4
91	Chief chemist	1	-	-	-	-	1
92	Analysis specialist	1	-	-	-	-	1
93	Analyst A	2	-	-	-	-	2
94	Analyst B	2	2	-	-	-	4
95	X-rays analyst	3	-	-	1	-	4
96	Laboratory tester B	2	-	-	-	-	2
97	Laboratory tester C	-	2	-	-	-	2
98	Laboratory services labourer	-	4	-	-	-	4
	Total	68	221	6	54	4	353

Annex V

JOB DESCRIPTIONS OF THE PROPOSED UNIDO EXPERTS

Planning mechanical engineer

Qualifications: University degree in mechanical engineering and at least seven years' experience in planning mechanical maintenance and organization of spare parts in the cement industry

Duties:

1. To study the current procedures of preventive maintenance and devise a more rational system;
2. To study the records maintained for machinery and equipment and analyse the particulars recorded about the life history of each part, average consumption of spares and maintenance material;
3. To study technical documents, drawings and suppliers' instructions, and establish guidelines for the upkeep of machinery and equipment;
4. To study procedures for oiling and greasing, revise specifications for oils and greases and analyse the circumstances of operation and maintenance;
5. To use these findings to plan preventive maintenance and its organization time units;
6. To programme oiling and greasing processes, oil changes, tabulation of oils and greases with running hours;
7. To simplify the reference numbers for greases and oils, unifying the distinguishing marks and specifications for the rational employment of local products;
8. To keep records of the use of spare parts in order to determine consumption and analyse anomalies in machine life;
9. To revise the reference numbers and technical specifications for spare parts so as to simplify the nomenclature and set up a comprehensive marking system;
10. To stipulate basic spares and production materials in terms of minimum, maximum and ordering stocks;
11. To work out a system for ensuring the regular supply of spares and production materials and to establish follow-up procedures for the whole cycle;

12. To inspect the departments and machines with a view to revising operational procedures, analysing difficulties and proposing solutions.

Maintenance mechanical engineer

Qualifications: University degree in mechanical engineering and at least seven years' experience in the mechanical maintenance of cement-making machinery

Duties:

1. To supervise normal mechanical maintenance, occasional repairs and general overhauling;
2. To keep registers for recording details of maintenance and repairs for illustrating the life history of machine parts and spares used;
3. To establish, over a period of time, the materials and staff required for maintenance;
4. To follow up the greasing and oiling programme, revise lubricant particulars and make substitutions according to maintenance schedules;
5. To inspect the mechanical behaviour of the machinery and equipment and work out technological solutions for any anomalies;
6. To participate in the implementation of modifications for improving productivity and eliminating undesirable incidents;
7. To supervise new erection work in accordance with general plans and possibilities for future extensions;
8. To rationalize the operation of the workshop machines so as to achieve maximum productivity;
9. To assist in the local manufacture of simple spare parts in the LCC workshop or in local facilities;
10. To give a comprehensive evaluation of offers and tenders, in terms of technical and economic factors;
11. To organize training programmes (seminars or on-the-job training) for mechanical maintenance personnel;

12. To put into effect a set of standards of industrial safety for personnel and machinery;

13. To report on mechanical maintenance and workshop activities and on the efficiency of personnel, and to propose improvements where necessary;

14. To rationalize the use of spares and maintenance materials through the establishment of economic principles and the promotion of higher standards of quality.

Maintenance electrical engineer

Qualifications: University degree in electrical engineering (power) with not less than seven years' experience in electrical maintenance in industrial establishments

Duties:

1. To establish programmes for electrical maintenance and general overhauling;
2. To supervise electrical maintenance and repairs and give technical advice on the rationalization of maintenance procedures;
3. To inspect electrical equipment, ensure its proper operation and rectify anomalies or disorders;
4. To supervise the erection of new electrical installations, study the loads of new machinery and equipment and plan the power supply;
5. To study the need for modifications in electrical equipment and participate in their execution in accordance with approved schedules;
6. To supervise the electrical workshop so as to assure the provision of the required services for maintenance and production;
7. To prepare lists of spares and materials needed for electrical maintenance, pointing out the minimum and ordering stocks and keeping records of maintenance particulars and spare-parts consumption;
8. To establish economic standards for meeting electrical maintenance and workshop requirements and to assist in the rational application of these standards;

9. To evaluate offers technically and economically to ensure rational selection;

10. To review the consumption of electrical power, compare it with normal rates and take steps to rectify any anomalies;

11. To implement measures intended to ensure the safe operation of machinery and the security of personnel;

12. To report on electrical maintenance and workshop activities;

13. To organize training programmes for personnel through seminars or on-the-job training.

Instrumentation electrical engineer

Qualifications: University degree in electrical engineering (communications) and not less than seven years' experience in the inspection, calibration and maintenance of measuring and control equipment in industrial projects

Duties:

1. To organize programmes for testing, calibrating and maintaining measuring and control equipment;

2. To inspect periodically the measuring and control equipment to assure its proper functioning, and to make tests and adjustments as required;

3. To supervise the maintenance and erection work for measuring and control equipment and telephone installations and to plan any extensions thereof;

4. To keep regular records on the maintenance particulars of measuring and control equipment so as to determine which spare parts must be ordered for ensuring an adequate stock;

5. To propose technical specifications for new orders and to evaluate offers in terms of technical and economic requirements;

6. To advise the staff of the instrumentation section on technical and administrative matters so as to raise their efficiency;

7. To report on the progress of maintenance work on the measuring and control equipment, and on the activities of the personnel in the instrumentation section;

8. To organize training programmes for personnel concerned with measuring and control equipment, for the purpose of reinforcing their knowledge of testing, calibration and maintenance;

9. To lay down the basic principles of industrial safety and to rationalize the process for attaining maximum protection through control equipment.

Annex VI

PROPOSAL FOR OPENING THE HAWA-EL-BARAG GYPSUM QUARRY

The lowermost level of gypsum formation in Hawa-El-Barag is so far below ground level that the quarry bottom will be subject to considerable accumulation of rain-water, which will hinder exploitation during the winter-time. The supply of gypsum to the plants should therefore be co-ordinated between the Rajma and Hawa-El-Barag quarries to ensure a continuous flow of material all year round to meet both present and future requirements.

Opening the quarry will involve removal of clay and limestone overburden and of waste material in the quarry bottom so as to have a clear quarry front with the full height revealing the whole gypsum stratum. The top layer will be prepared for drilling and blasting. The clay and limestone ingredients should be heaped in proper locations. Access will be through a road extending from the paved main road down to the quarry bottom with a suitable slope, the surface to be covered with crushed limestone excavated during the quarry opening.

The access road should be properly levelled, water-sprayed and adequately compacted for the easy passage of gypsum lorries. A drain-pipe should be laid adjacent to the paved road for disposal of rain-water.

Site

Hawa-El-Barag is located on the vertical co-ordinate 444 300/444 800 and the horizontal co-ordinate 3 557 000/3 557 500. It is accessible by the paved road 13.5 km from Rajma village (1.07 km eastwards along Rajma-Ebiar road then 2.7 km northwards along Jira road); the quarry site is only 300 m from the paved road.

Exploitation levels

The neighbourhood is a plain ranging in elevation from 296.2 to 303 m above sea level. The bottom of the existing pit is at 270 m. The pit has an oval shape, 62 m long in the direction NE/SW and 38 m wide in the direction NW/SE. The gypsum formation is in the form of interlocked lenses 2.0-17.6 m thick, covered by clay and limestone overburden varying from 1 to 20 m thick.

Gypsum texture

The formation is distinguished by its needle-crystalline texture within compact clusters of a pure lustrous appearance. It was formed by sedimentation, whereby the gypsum is crystallized in depressions as lenses which are interrupted by transverse faults disturbing the horizontal planes. There are several caverns with various orientations and sizes, as large as 10 m in some cases. This will necessitate taking great precautions for the safety of personnel and equipment. The gypsum varies in colour from light grey to light brown. In some spots it is interrupted by intercalations of limestone or marl, and sometimes anhydrite can be distinguished by its bright white colour.

Opening the quarry

The clay and limestone overburden should be removed to leave a circumferential strip with a minimum breadth of 30 m around the borders of the quarry front. The quarry bottom should be cleared of foreign materials to expose the gypsum formation. The gypsum should then be sufficiently quarried to penetrate to the bottom of the gypsum formation and shape the quarrying area into a regular quarry front. All materials should be transported to a specified area, where they should be separated into stockpiles for easy measurement. The stockpiles should be situated at least 50 m away from the paved road, 100 m away from the high-tension power line, and preferably 500 m away from the gypsum deposit.

There is a temporary road leading to the quarry bottom, which can be used in the beginning for transporting gypsum and waste material to the storage areas. Care should be taken to avoid contaminating the gypsum with the waste materials. Pure gypsum is required, as devoid of undesirable ingredients as possible. Limestone overburden should be transported separately and kept clean so that it can be utilized as the base for the quarry access road. According to preliminary estimates, 15,000 m^3 of gypsum and 150,000 m^3 of limestone and clay overburden will be excavated. These estimates may be increased or decreased within ± 25% limits, according to actual exploitation circumstances, provided that the company issues an official notice to the contractor accordingly. A tolerance of ± 10% will be allowed in the final quantities. The settlement will be done in terms of cubic metres of stockpiled material. A separate offer will be quoted for delivery of gypsum loaded on the company trucks, which should not, however, conflict with progress in opening the quarry. The gypsum may be stockpiled at site whenever the trucks are not sufficient to remove it quickly enough.

Access to the quarry

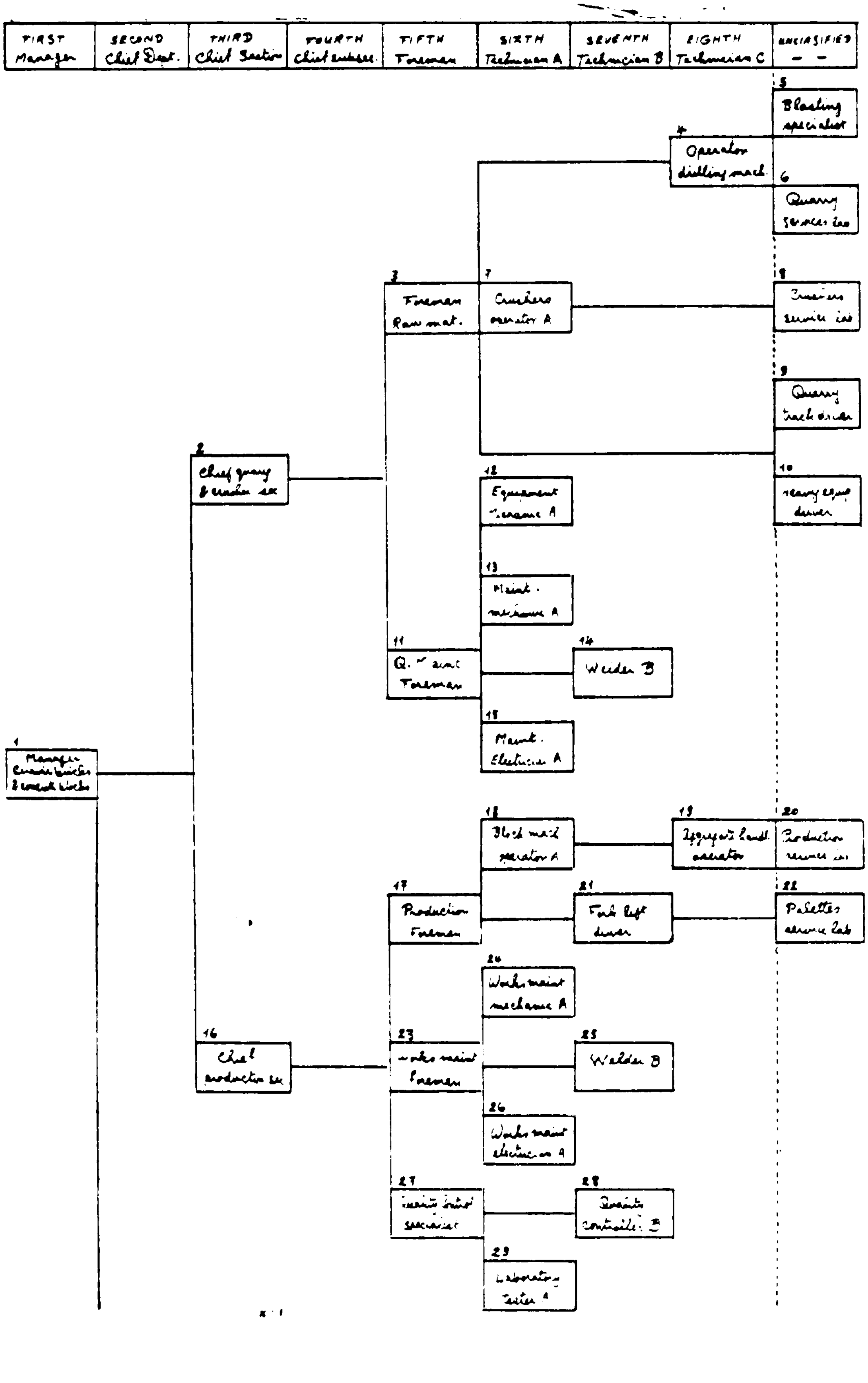
A road has to be built from the main asphalt road down to the quarry bottom, with a length of 300 m, width of 6 m and slope of 1:8. It should cross the shortest distance and be designed to take into account area and inclination. The road area should be dug down to solid soil in the required direction. The excavated soil should be removed from the site and the road basement adjusted to the proper slope. Any eventual depressions should be refilled with crushed limestone, using the following procedure. Crushed limestone for the road base should be obtained from limestone waste blasted from overburden. It should be spread in layers of 20 cm thickness to the required levels, up to 50 cm total thickness. Each layer should be levelled, water-sprayed and compacted to form a solid body with an even surface. The crushed limestone should be homogeneous, devoid of any impurities, clay or organic matter. The surface should end with a convex cross section so that rain-water automatically drains off of the road. The longitudinal levels should be checked with a ruler 4 m long so as to ensure axial evenness.

Drainage of rain-water

A drain-pipe should be laid at the side of the asphalt road at its junction with the quarry access road. A concrete pipe 30 cm in internal diameter and 9 m in length should be laid on a concrete foundation 25 cm thick. It should be covered with a surface layer of reinforced concrete with a minimum thickness of 30 cm. The slope of the pipe will be 2%, continuing to the rain-drainage canal originally provided beside the asphalt road. Where the concrete pipe joins the drainage canal at the inlet and outlet, a protective covering should be built consisting of solid rock and cement-sand mortar (300 kg cement/m^3 sand). The covering should be waterproofed by plastering with cement-sand mortar (500 kg/m^3 sand) in accordance with standard specifications for building materials.

Annex VII

PROPOSED ORGANIGRAM FOR PERSONNEL
OF THE CONCRETE-BLOCKS PLANT



Annex VIII

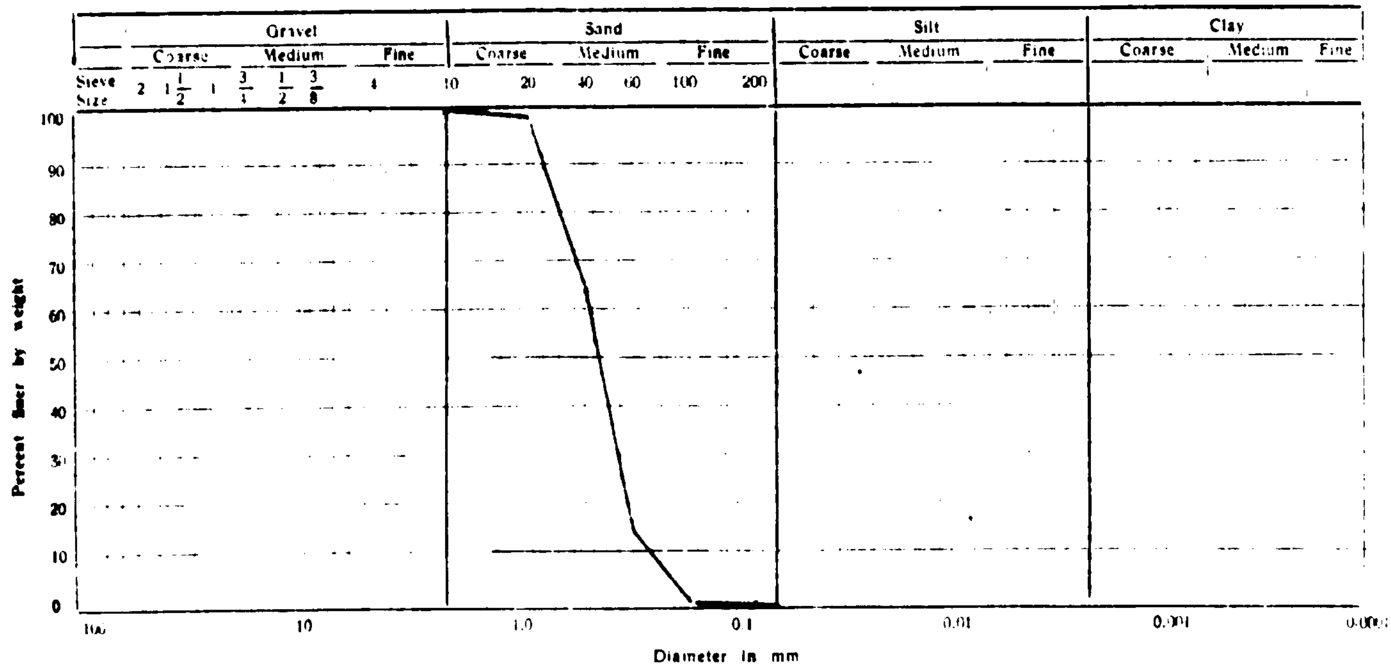
EMPLOYMENT PROPOSAL FOR PERSONNEL OF THE CONCRETE-BLOCKS PLANT

Job No.	Position	Department or section	Local personnel First stage	Local personnel Second stage	Outside tech. assist.	Total
1	Plant manager		1	-	-	1
2	Chief, quarries and crushers	Quarries	1	-	-	1
3	Quarry foreman	Quarries	-	1	-	1
4	Drilling operator C	Quarries	1	1	-	2
5	Blasting specialist	Quarries	1	-	-	1
6	Quarry services labourer	Quarries	1	1	-	2
7	Crushing plant operator A	Crushers	-	2	-	2
8	Crusher services labourer	Crushers	-	2	-	2
9	Quarry truck driver	Supplies	1	5	-	6
10	Heavy equipment driver	Supplies	1	2	-	3
11	Quarry maintenance foreman	Quarry maint.	-	-	1	1
12	Equipment mechanic A	Quarry maint.	1	-	-	1
13	Maintenance mechanic A	Quarry maint.	-	-	1	1
14	Welder B	Quarry maint.	-	1	-	1
15	Maintenance Electrician A	Quarry maint.	-	1	-	1
16	Chief of production	Production	-	-	1	1
17	Production foreman	Production	-	1	-	1
18	Block machine operator A9	Production	-	2	-	2
19	Aggregate handling operator	Production	-	2	-	2
20	Production services labourer	Production	-	6	-	6
21	Fork-lift driver	Production	-	4	-	4
22	Palette services labourer	Production	-	2	-	2
23	Workshop maintenance foreman	Workshop maint.	-	-	1	1
24	Workshop maintenance mechanic A	Workshop maint.	-	-	3	3
25	Welder B	Workshop maint.	-	1	-	1
26	Workshop maintenance electrician A	Workshop maint.	-	-	1	1
27	Quality control specialist	Laboratory	-	-	1	1
28	Quality controller B	Laboratory	1	1	-	2
29	Laboratory tester A	Laboratory	1	-	-	-
	Total		10	35	9	54

Annex IX

GRANULOMETRIC ANALYSIS
OF GEMINIS SAND USED IN
TESTS ON CONCRETE BLOCKS

Item No.	Sieve No.	Aperture (mm)	Retained residue (%) Individual	Cumulative
1	10	2.000	-	-
2	20	0.840	1.0	1.0
3	40	0.420	36.0	37.0
4	60	0.250	48.0	85.0
5	100	0.149	14.0	99.0
6	200	0.074	1.0	100.0



Annex X

PHYSICAL TESTS OF CEMENT SAMPLE USED FOR CONCRETE TESTS

Cement produced on:	13 March 1977
Manufactured and tested according to:	Libyan Standard Specification 21/72
Specific surface area (Blaine):	3250 cm^3/g
Setting time	
Initial:	2 hours, 25 minutes
Final:	3 hours
Expansion (Le Chaterlier):	1 mm
Comprehensive strength	
After 3 days:	294 kg/cm^2
After 7 days:	398 kg/cm^2
Water used in gauging	
Compressive strength :	10%
Paste of standard consistency :	25.2%

Annex XI

CHEMICAL ANALYSES OF SAMPLES
USED FOR CONCRETE BLOCKS

Component	LCC cement (%)	Geminis sand (%)	H. Magzaha limestone (%)	S. Magzaha limestone (%)
$CaCO_3$	-	96.00	87.75	97.00
SiO_2	20.88	0.85	7.32	3.17
Al_2O_3	6.02	1.08	2.15	0.90
Fe_2O_3	2.08	0.00	1.00	0.40
CaO	61.82	51.34	44.16	45.82
MgO	2.50	2.60	3.70	2.10
SO_3	2.01	-	0.11	0.18
K_2O	0.96	0.03	0.18	0.08
Na_2O	0.32	0.08	0.08	0.03
LOI	2.36	44.00	40.24	43.68
Total	98.95	99.98	98.94	96.36
LSF	0.90			
SR	2.58			
AM	2.89			
C_3S	34.01			
C_2S	34.25			
C_3A	12.43			
C_4AF	6.32			

Annex XII

CHEMICAL ANALYSIS OF A WATER SAMPLE FROM THE SAADAWYIA WELL OF THE CONCRETE-BLOCKS PLANT

	mg/litre
pH	8.32
Alkalinity (TAC)	87.5
Total hardness ($CaCO_3$)	65.3
Calcium	23.8
Magnesium	41.5
Sodium	812.0
Potassium	30.1
Chloride	450
Nitrate	0.57
Sulphate	443.5
Dry residue	3165
Calcined residue	2394
Loss	771
Dissolved silica	14.5

Annex XIII

CHARACTERISTICS OF CONCRETE MIXES TESTED FOR THE CONCRETE-BLOCKS PROJECT

Series A: comparison of stone types

Description of test samples	Soft limestone (test A1)		Hard limestone (test A2)		Average crushed stone (test A3)	
	%	g	%	g	%	g
Aggregate size						
0 - 0.150	5	225	5	225	5	225
0.150 - 0.297	10	450	10	450	10	450
0.297 - 0.590	15	675	15	675	15	675
0.590 - 1.180	15	675	15	675	15	675
1.180 - 2.380	15	675	15	675	15	675
2.380 - 4.760	15	675	15	675	15	675
4.760 - 9.520	25	1 125	25	1 125	25	1 125
Total	100	4 500	100	4 500	100	4 500
Fineness module	3.70		3.70		3.70	
Normal cement (g)	400		400		400	
Saadawyia well water (g)	500		500		500	
Compressive strength (kg/cm^2)						
After 7 days	14		90		16	
After 28 days	36		187		66	

Series B: comparison of concrete mixes using various combinations of beach sand and limestone dust components

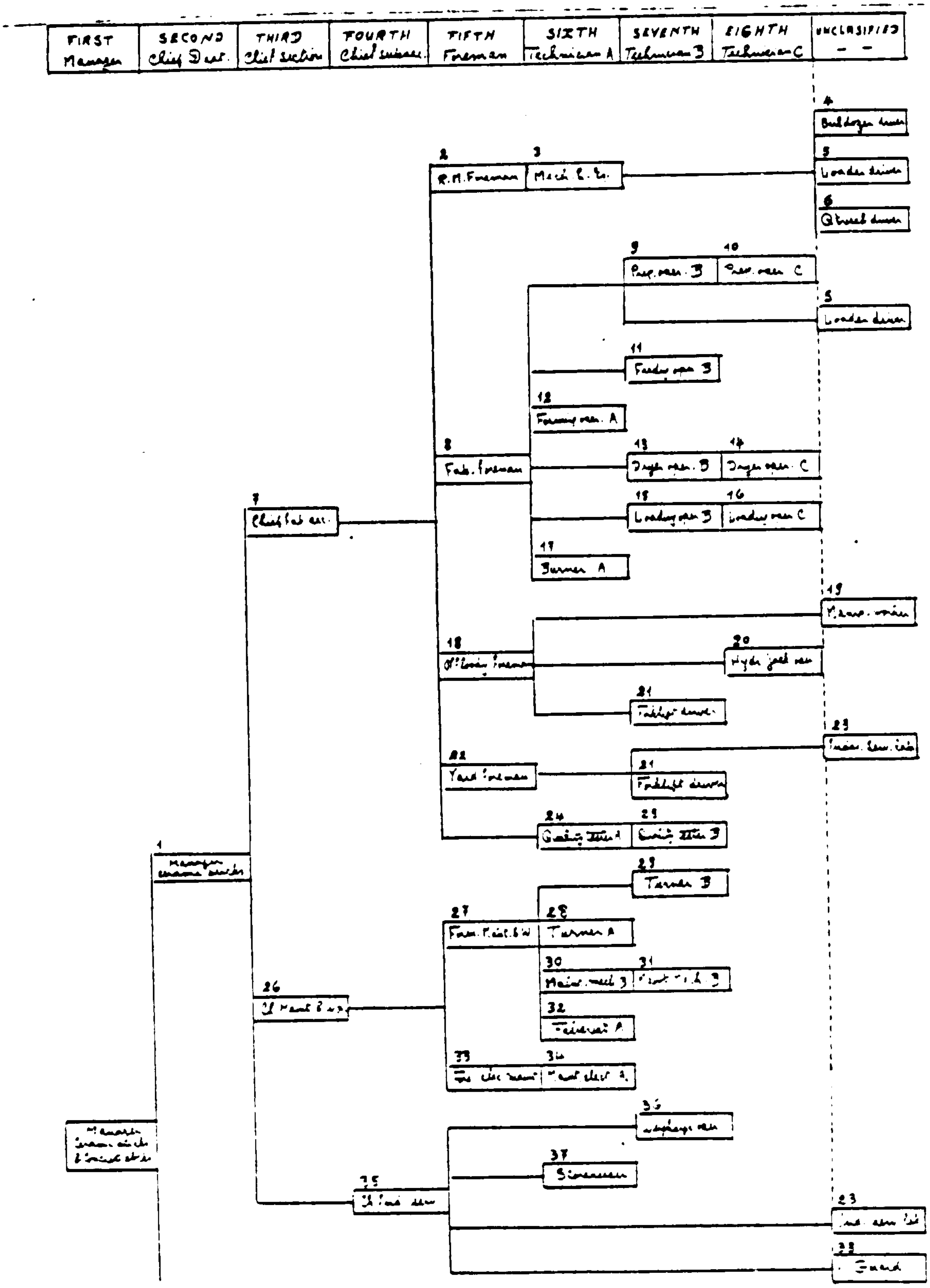
Descriptions of test samples	Average aggregate, with beach sand or limestone dust added							
	Test B1		Test B2		Test B3		Test B4	
	%	g	%	g	%	g	%	g
Aggregate size								
0. - 0.150	6.8	306	5.7	257	3.0	135	0.8	36
0.150 - 0.297	6.9	311	4.0	180	6.6	297	0.7	32
0.297 - 0.590	15.2	684	7.0	315	20.0	900	3.5	157
0.590 - 1.180	13.6	612	10.6	477	16.2	729	10.0	450
1.180 - 2.380	16.3	734	16.3	734	15.4	693	15.4	693
2.380 - 4.760	20.7	932	20.7	932	19.6	882	19.6	882
4.760 - 9.520	20.5	921	20.5	932	19.2	864	19.2	864
Geminus sand	-	-	15.2	682	-	-	30.8	1 386
Total	100	4 500	100	4 500	100	4 500	100	4 500
Fineness Modulus	3.70		3.70		3.70		3.70	
Normal cement (g)	400		400		400		400	
Saadawyia well water (g)	500		500		500		500	
Compressive strength (kg/cm^2)								
After 7 days	61		103		61		35	
After 28 days	99		168		82		77	

Series C: Effect of higher fitness modulus

Description of test samples	Average aggregate, with beach sand or limestone dust added							
	Test C1		Test C2		Test C3		Test C4	
	%	g	%	g	%	g	%	g
Aggregate size								
0 - 0.150	6.7	302	6.3	283	2.5	113	0.9	41
0.150 - 0.297	5.5	248	4.4	198	5.2	235	0.8	36
0.297 - 0.590	11.0	495	7.8	351	16.5	743	3.9	176
0.590 - 1.180	13.0	585	11.8	531	15.7	707	11.0	496
1.180 - 2.380	18.0	815	18.1	815	17.0	766	17.0	766
2.380 - 4.760	23.0	1 035	23.0	1 035	21.7	977	21.7	977
4.760 - 9.520	22.7	1 020	22.7	1 021	20.9	959	21.3	959
Geninis	-	-	5.9	266	-	-	23.3	1 049
Total	100	4 500	100	4 500	100	4 500	100	4 500
Fineness modulus	3.90		3.90		3.90		3.90	
Normal cement	400		400		400		400	
Saadawyia well water	500		500		500		500	
Compressive strength (kg/cm^2)								
After 7 days	111		119		56		50	
After 28 days	156		174		89		95	

Annex XIV

PROPOSED ORGANIGRAM FOR PERSONNEL
OF THE CERAMIC-BRICKS PLANT



Annex XV

EMPLOYMENT PROPOSAL FOR PERSONNEL OF THE CERAMIC-BRICKS PLANT

Job No.	Position	Production section	Local personnel	CERIC contract	Management contract	Total
1	Technical manager		-	1	-	1
2	Raw materials foreman	Quarries	1	-	-	1
3	Mechanic, heavy equipment	Quarries	1	-	-	1
4	Bulldozer driver	Quarries	1	-	-	1
5	Loader/scraper driver	Supplies	4	-	-	4
6	Quarry truck driver	Supplies	2	-	-	2
7	Chief, fabrication section	Fabrication	-	1	-	1
8	Fabrication foreman	Fabrication	2	2	-	4
9	Preparation operator B	Preparation	-	-	2	2
10	Preparation operator C	Preparation	2	-	-	2
11	Feeding operator B	Preparation	2	-	-	2
12	Forming operator A	Forming	2	-	2	4
13	Dryers operator B	Forming	1	-	-	1
14	Dryers operator C	Forming	1	-	-	1
15	Loading operator B	Forming	-	-	2	2
16	Loading operator C	Forming	2	-	-	2
17	Burner A	Kilns	1	-	2	3
18	Off-loading foreman	Off-loading	1	-	-	1
19	Manipulation worker	Off-loading	16	-	-	16
20	Hydraulic jack operator	Off-loading	4	-	-	4

Job No.	Position	Production section	Local personnel	CERIC contract	Management contract	Total
21	Forklift driver	Off-loading	6	-	-	6
22	Yard foreman	Yard	2	-	-	2
23	Industrial services labourer	Yard	8	-	-	8
24	Quality tester A	Laboratory	-	-	1	1
25	Quality tester B	Laboratory	1	-	-	1
26	Chief, maintenance and workshop	Workshop	1	-	-	1
27	Foreman, maintenance and workshop	Workshop	1	-	-	1
28	Turner A	Workshop	1	-	-	1
29	Turner B	Workshop	1	-	-	1
30	Maintenance mechanic A	Workshop	1	-	1	2
31	Maintenance mechanic B	Workshop	2	-	-	2
32	Clerk A	Workshop	1	-	1	2
33	Foreman, electrical maintenance	Electrical maint.	-	-	1	1
34	Maintenance electrician A	Electrical maint.	2	-	-	2
35	Chief, industrial services	Industrial services	1	-	-	1
36	Weighbridge operator	Industrial services	1	-	-	1
37	Storekeeper	Industrial services	1	-	-	1
38	Guard	Industrial services	5	-	-	5
	Total		78	4	12	94

Annex XVI

CALCULATION OF A RAW-MIX DESIGN FOR THE SOUK-EL-KHAMIS CEMENT PROJECT

Amelioration of the silica ratio in the clay

The silica ratio (SR) is given by the formula:

$$SR = \frac{(SiO_2)}{(Al_2O_3)+(Fe_2O_3)}$$

where (SiO_2), (Al_2O_3) and (Fe_2O_3) are the proportions of silica, alumina and ferric oxide in the mixture in weight per cent. The SR of the clay can be reduced by mixing iron ore with it in the proportion 90% clay : 10% iron ore, as can be seen from the following table, which gives the percentage composition of the raw materials and the 90 : 10 mixture.

Components	Raw materials			90 : 10 mixture		Total
	Limestone	Clay	Iron ore	From clay	From iron ore	
SiO_2	3.75	65.62	5.86	59.06	0.59	59.65
Al_2O_3	0.45	13.11	5.20	11.80	0.52	12.32
Fe_2O_3	0.24	6.53	72.61	5.88	7.26	13.14
CaO	51.27	2.94	0.33	2.65	0.03	2.68
MgO	0.43	3.40	2.41	3.06	0.24	3.30
LOI	41.86	7.62	11.18	6.86	1.12	7.98
SR	8.33	3.34	0.08			2.34

Implication of Bogue formula

The lime saturation factor (LSF) of a clinker is given by the formula:

$$LSF = \frac{(CaO)}{2.8\,(SiO_2) + 1.18\,(Al_2O_3) + 0.65\,(Fe_2O_3)}$$

where (CaO), (SiO_2), (Al_2O_3), (Fe_2O_3) are the proportions of calcium oxide, silica, alumina and ferric oxide in the clinker in weight per cent.

The proportions of the components of a clinker with LSF = 0.93 can be calculated using the formula above, rearranged as follows:

$$(CaO) = 0.93\ [2.8\,(SiO_2) + 1.18(Al_2O_3) + 0.65(Fe_2O_3)]$$
$$= 2.604(SiO_2) + 1.097(Al_2O_3) + 0.605\,(Fe_2O_3)$$

from which the (CaO) in the potential clinker from the components is calculated:

Component of raw mix	(CaO) Original component	(CaO) Potential clinker	Excess supplied	To be supplied
Limestone	51.27	10.40	40.87	
90 : 10 mixture	2.68	176.79		174.11

Proposed raw-mix composition

The relative amounts of limestone and 90:10 mixture in the raw mix are now obtained by balancing the excess (CaO) in the limestone with the deficit (CaO) in the 90:10 mixture, as follows:

Limestone: $\dfrac{174.11}{174.11 + 40.87} \times 100 = 81.0\%$

Clay $(100 - 81) \times 0.90 = 17.1\%$

Iron ore $(100 - 81) \times 0.10 = 1.9\%$

The following table gives the composition of the mix and resulting clinker:

Components	Designed raw mix: Limestone (81.0%)	Clay (17.1%)	Iron ore (1.9%)	Total (100.0%)	Clinker
SiO_2	3.04	11.22	0.11	14.37	22.25
Al_2O_3	0.36	2.24	0.10	2.70	4.18
Fe_2O_3	0.19	1.12	1.38	2.69	4.17
CaO	41.50	0.50	0.01	42.01	65.05
MgO	0.35	0.58	0.05	0.98	1.52
LOI	33.91	1.30	0.21	35.42	-

The quality factors of the clinker

LSF = 0.93 (as designed)

SR = 2.66

Alumina modulus (AM) = $\dfrac{(Al_2O_3)}{(Fe_2O_3)} = 1.00$

Compounds content

C_3S = 4.07(CaO) - 7.6(SiO_2) - 6.72(Al_2O_3) - 1.43(Fe_2O_3) = 61.60%

C_2S = 2.87(SiO_2) - 0.754 C_3S = 17.41%

C_3A = 2.65(Al_2O_3) - 1.69 Fe_2O_3 = 4.03%

C_4AF = 3.04 Fe_2O_3 = 12.68%

where C represents (CaO)

S " (SiO_2)

A " (Al_2O_3)

F " (Fe_2O_3)

C-721

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