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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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ASSISTANCE TO HEAVY CLAY AND CERAMIC INDUSTRIES
UC/PDY/83/133
DEMOCRATIC YEMEN

PDR Yemen.

Technical report: Establishment of a clay brickmaking factory

Prepared for the Government of Democratic Yemen
by the United Nations Industrial Development Organization

Based on the work of W. Buchanan, brickmaking consultant

V.86-50030
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Explanatory notes

The monetary unit in Democratic Yemen is the dinar (YD). One dinar has 1.000 fils.

References to tonnes (t) are to metric tonnes.

ESCWA refers to the Economic and Social Commission for Western Asia.

Mention of the names of firms and commercial products does not imply endorsement by the United Nations Industrial Development Organization (UNIDO).

ABSTRACT

Within the context of the project "Assistance to heavy clay and ceramic industries" (UC/PDY/83/133), a consultant was engaged by the United Nations Industrial Development Organization (UNIDO) to assist the Government of Democratic Yemen in its endeavours to develop a brick factory. The duration of his mission was three weeks, starting on 29 October 1985.

A number of raw materials studies had already been carried out with respect to clay deposits near Aden and various recommendations made to the Government. The consultant examined these recommendations, including the results of various clay tests, and came to the conclusion that whilst the test results and subsequent conclusions were, for the most part, reasonable, the proposals for establishing brickmaking facilities should have been based upon a detailed market study and realistic cost/benefit data.

The consultant strongly recommends that a detailed market and technical study be undertaken. Such a study would consider the place of a brickmaking factory in the overall context of building (wall) materials, raw materials, the building industry, existing investments in the building-materials industry and the options for developing existing or new facilities.

He further recommends that UNIDO should consolidate the remaining funds within the project to help finance the above study, and seek any additional funds which may be necessary. It will, of course, be essential for the Government to make the necessary request through the relevant channels.

The report also contains a brief description of a mobile brickmaking facility which could be used as a small pilot plant as well as for training purposes, some observations following a field mission to Al Mukalla and Saywun and other general observations.

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INTRODUCTION

The principal objective of this mission which was carried out under the project "Assistance to heavy clay and ceramic industries" (UC/PDY/83/133), was to assist the Government of Democratic Yemen in establishing a clay brick factory. To this end a consultant was attached to the Ministry of Industry at Aden.

Preliminary discussions took place in the Ministry on 30 October 1985 during which it was agreed that in his study the consultant should consider the following:

(a) A number of raw materials evaluations which had already been made with respect to clay deposits near Aden and some proposals relating to brick- and tilemaking factories. The consultant should examine these, and clarify and evaluate them for the Ministry;

(b) The fact that virtually all construction work at Aden was effected as far as concrete or cement-based products are used. Where reinforced concrete was employed in the coastal regions, corrosion of the reinforcing iron was a serious problem;

(c) The fact that a new factory for Portland cement is planned to be erected in the near future;

(d) The existence of traditional and other building (wall) materials, as well as other related factors such as existing design and building trades skills, alternative products, and the overall need for the Government to make the best choice based on detailed knowledge of the available options.

Based on the above it was agreed that the establishment of a brick factory should not and could not be made in isolation from other sectors of the building materials and related industries. In order that a wider view of the building materials industry in the country could be established and all the necessary discussions and site visits made, including some to other Governorates, it was considered essential to extend the mission from its original duration of two weeks to three weeks. An agreement on this extension was reached between the Ministry of Industry, UNDP and UNIDO and thus the consultant's mission lasted from 29 October until 20 November 1985.

In order that the Ministry of Industry and UNDP would have early information on the findings and conclusions of the mission, the consultant prepared three handwritten reports, copies of which were left with the Ministry and UNDP. These reports covered the following:

Report No. 1 - Raw materials studies and proposals for a brick factory
Report No. 2 - Mobile brickmaking facility
Report No. 3 - Al Mukalla and Saywun.

The present report summarizes the above three reports and consolidates other findings and related information.

The annexure 1 to report No. 1 containing the "Terms of reference for a techno-economic feasibility and market study for the production of building (wall) materials in Democratic Yemen" is reproduced as annex I, since it is considered to be a primary recommendation and essential to the future efficient development of the building (wall) materials industry.

Annex II is a list of the consultant's principal contacts during his mission.

RECOMMENDATIONS

1. A techno-economic feasibility and market study should be carried out, as detailed in annex I to this report. The study should be implemented through the Industrial Studies Department of the Ministry of Industry.

2. UNIDO should consolidate the balance of funds in project UC/PDY/83/133 and seek any additional funds required to ensure that the study can be completed.

3. In requesting UNIDO to execute the study, the Government should indicate those companies or organizations whom it considers should be invited to tender. These would be added to any list of companies or organizations which UNIDO can put forward. The Government should be consulted for confirmation as to the acceptability of the companies or organizations who UNIDO considers to have submitted the best tenders. The curricula vitae of all personnel who would participate in the study in Democratic Yemen should also be submitted to the Government.

4. Since the proposed techno-economic feasibility and market study is considered to be the prime recommendation of this report, UNIDO should maintain regular contact with the Government of Democratic Yemen to assist in formulating the request for the study and in any subsequent evaluation and implementation stage.

5. Since the clay materials at Jawala, Fiyush and Mendara are by no means ideal, it is recommended that:

(a) Exploitation initially be based on making bricks up to a size of 290 x 90 x 90 mm, and that the production of blocks should be developed later;

(b) Further geological and test work be carried out in the area, including as far as Lahej and Suffian, to determine if better quality material is available. The variations in quality should be determined in both lateral and vertical directions;

(c) Any such further physical test work be carried out in the Materials Testing Laboratory of the Ministry of Construction as a means of developing expertise within the country. If necessary, technical assistance (bilateral or multilateral) should be requested for the provision of equipment and training;

(d) The Geological Survey Department, in co-operation with the Ministry of Construction, indicate if it requires any special assistance in surveying for and evaluating deposits of heavy clays or other non-metallic minerals.

6. With respect to the so-called "cold-processed crystallized clay" process, it is recommended that any investment should be subsequent to the techno-economic feasibility and market study showing that this product or range of products is technically and economically desirable. This recommendation is equally applicable to the production of burnt clay blocks.

7. A technical evaluation should be made of current or potential lime and gypsum producing areas to see if and how production can be developed or made more efficient and to advise in detail on the efficient and diverse uses of the products.

8. UNIDO should forward all available information on building materials to:

(a) The Ministry of Industry (Building Materials Officer, Department of Industrial Studies);

(b) The Assistant Deputy Minister of Construction, Ministry of Construction;

(c) The Deputy Director, Geological Survey Department.

I. BACKGROUND

Following a request by the Government of Democratic Yemen, through the United Nations Development Programme (UNDP), to the United Nations Industrial Development Organization (UNIDO) to assist in the establishment of a clay brickmaking factory, UNIDO engaged a consultant to execute the following duties:

(a) To assist the Government in establishing a clay brick factory and, to this end, review jointly with the national project team the technical assistance inputs for the subject project and prepare:

(i) A job description for the expert (or experts) to be assigned to the project for a total duration of four man-months;

(ii) A description of raw material tests to be undertaken abroad (or, if facilities exist, in the country);

(iii) A detailed project workplan to ensure the smooth implementation of project activities which are expected to start in 1985;

(b) If necessary, to supervise the collection of representative samples (clays) from potential project areas, and to finalize arrangements for their shipment abroad for testing purposes.

Democratic Yemen, which is situated in the south-western corner of the Arabian Peninsula, has a territory of 208,000 km^2 and a coastline extending from Bab el Mandab in the south-west to the borders of Oman in the north-east. The population of the country is 2.06 million. Of this, some 33 per cent is thought to live in urban areas and there is a nomad population of around 10 per cent. The official language is Arabic but English is also widely used. The major port and airport are at Aden, with Mukalla being the second major port and airport.

The city and Governorate of Aden is the most densely populated part of the country and it has been said that some 70 per cent of all building materials are used there. Until 1976 there was a small, partly mechanized brick factory at Mindara on the outskirts of Aden. Although the buildings and some of the extrusion equipment are still there, production ceased due to a combination of factors which were said to include lack of expertise (the original owners left the country), high fuel costs for the wood-fired Bull's Trench and Scotch kilns, and equipment failure. There is a stack of several hundred air-dried bricks lying in the open, still in relatively good condition in spite of having been exposed to the weather for some nine years.

The principal wall materials used in Aden and for much of the public works in other parts of the country are concrete blocks and precast panels. In the Hadramout Governorate these Portland-cement based products are also used, but major deposits of limestone are being utilized to produce cut blocks and slabs, undressed blocks and dressed blocks. In many parts of the country sun-baked bricks are produced by the private sector and used to build multi-storey structures which, taking the historic town of Shibam as an example, have a life potential of several hundred years.

It would be difficult not to be impressed by the efforts which the Government has made to upgrade the standards of housing for the population and to eliminate the sub-standard and slum dwellings. In order to obtain maximum benefits in the future, from what are limited government resources, the

establishment of a brick factory is being looked at against the broader background of the needs to provide wall materials which can be produced and used with the country's own resources of materials and manpower.

The production, sales and use of clay bricks are influenced by a number of factors, some of which are:

(a) The market for the products which determines both the types of products (size, shape, strength etc.) and the volumes of each type which are required;

(b) The raw materials available to make the requisite types and volumes of products. This is linked with the technology to be used to process the raw materials;

(c) The various skills required to design efficient structures, i.e. cost efficient in design and utilization of materials; to produce the bricks efficiently in terms of cost and quality; and to use the products such that the cost "in the wall" is as low as possible;

(d) Substitute or alternative building materials which may compete on the basis of cost, availability or for other reasons.

It will be appreciated that the above factors are linked and in considering a brick factory, all these and other factors should be taken into account.

In terms of variety of uses, burnt clay bricks are probably the most versatile of all bricks made. They have proven to be the most durable as is evidenced by the existence of structures made more than a thousand years ago. However, determining factors in considering which type of brick may be the optimum choice include those related to the end use of the brick and the basic adequacy of the product to serve that use. Thus there are many cases where bricks of lower quality are adequate for the intended use and where a brick of higher quality is not essential. Since higher quality usually also entails a higher price, it is necessary to evaluate the range of available products and their use to determine which options are available and which will give the best value.

II. FINDINGS

The findings are in sections A to C and are directly related to the respective handwritten reports which the consultant left with the Ministry of Industry.

A. Raw materials studies and proposals for a brick factory

Several raw materials studies have been made and some proposals put forward for the establishment of brick- and tilemaking factories. The consultant has studied those reports and some of the salient points are referred to below with comments.

1. Research report for bricks and wall tiles, EKEA Aktiengesellschaft, D-7500 Karlsruhe 41, Greschbachstrasse 23, Federal Republic of Germany, October 19?8

The report is a comprehensive study of clays from the deposits at Fiyush and Jawala, near Aden. Tests were also carried out to see if sea water could be used instead of fresh water. The report gives reasonably detailed advice on factory location and makes an estimate of raw material reserves.

The evaluation of results notes that certain areas of the deposits are too silty-sandy to make bricks but a sufficient amount of the deposit is suitable for the production of wet extruded bricks with "... a reasonable amount of perforations". A figure of 45 per cent perforations is later suggested as being possible. With 45 per cent perforations, a block of an actual size of 400 x 200 x 200 mm would weigh up to 16.5 kg. The report indicates that the stiff extrusion process could also be used.

The use of salty water was evaluated and was considered to be the probable cause of efflorescence. However, it is stated that:

> "As already mentioned, and proved, the condition can be alleviated by covering the extruded material with gum. The technical behaviour of the material will evidently not be influenced by the use of sea water" and "As yet no tests have been carried out as to the efflorescent properties of the burnt ware as these take long periods of time to perform."

As far as the proposed location of the brick factory is concerned, the report refers to the drilling of wells and thus appears to assume that fresh water will be used in the process.

Wall tiles were considered to be a possibility and the report states:

> "... the impression was that the tested raw materials, except for Jawala VI, may be used in the manufacture of wall tiles with a beige-brown colour as a base. [illegible]tives will be necessary in each case to combat the tendency to warpi[illegible]. Besides, the quality demands for wall tiles in South Yemen are unknown to us, so that we did not carry out any quality tests. It is, therefore, not to be ruled out, that improvements of certain other qualities (hardness etc.) will require different additives. More accurate information on these materials in the production of wall tiles and the required amounts and types of additives required can only be reached in the form of a development scheme."

The test results using clays plus kaolin from the area of Iramus have indicated that wall tiles could be made, but that further test work was necessary. The report indicated that both dry and wet production methods could be suitable. The production process would be different from that used for brickmaking.

From the test results and observations, it is apparent that the clays from Fiyush and Jawala are sensitive to drying, have limitations with respect to extrusion where the water content must be carefully controlled, and are subject to rapid vitrification if fired over the equivalent of a laboratory temperature of 1,060°C (different laboratories may obtain different numerical results due to differences in their test methods). The report also considers that there are adequate proven reserves of clay, with the likelihood that further reserves could be available in the vicinity.

The report states that a clay sample from "Suffian Lahej" extruded well and in fact was considered to be the best from that point of view. However, it is not clear as to which specific location the sample was taken from or to what extent it was representative of a deposit. During the course of the present mission the consultant visited both Suffian and Lahej which are in the Lahej Governorate, close to Aden, and noted that there has been, and still is, much use of sun-baked bricks in the area.

In conclusion, whilst it has been considered that it will be feasible to make burnt clay bricks from the materials examined by EKEA, careful selection of the raw materials is essential, followed by close control of the process during production. From a technical and probably also from an economic point of view, it would probably be easier to make bricks rather than blocks, i.e. bricks of up to 290 x 90 x 90 mm as compared to blocks of 400 x 200 x 200 mm.

2. "Pragoinvest" - Foreign Trade Corporation for the Export and Import of Machines, Machinery Equipment and Complete Plans, P.O. Box 12, Praha 8, Czechoslovakia, reference 316/908/77, code 316/4440, June 1977

This is simply a tender document for the supply of equipment for a brick and floor-tile factory with capacities of 25 million bricks and 100,000 m^2 of floor tiles per year. The cost of the factory was given as:

Supply and supervision of installation	$US 3,623,550
"Machinery-technological project" plus unspecified costs for technical assistance	$US 80,000

Under the "project part" of the report it is stated:

"Basic data

"The technological report has been worked out on the basis of the tender of the Ministry of Industry, PDRY, Aden. The geological and technological survey proper of the localities will be carried out according to the requirements of the customer."

From this it has been assumed that the factory design has been based on prior experience with this type of factory rather than on specific raw material characteristics.

Details were given of the sizes and volumes of bricks and tiles to be made plus various calculations on drying and firing. Drying was to be effected in a chamber dryer and firing in an annular kiln. However, if, as

assumed, the calculations are not based on a proper survey of the raw materials, those calculations and the proposed production methods must be viewed with caution.

3. Report on the feasibility of clay brick manufacturing plant in the Peoples' Democratic Republic of Yemen, Japan Consulting Institute, March 1978

This report is the result of a mission of approximately three weeks to Democratic Yemen by three Japanese ceramic engineers, followed by laboratory tests and evaluations in Japan. With respect to the market for bricks as calculated by the team, it would appear that housing plans from the Ministry of Housing have been used and the quantities of concrete blocks required have been converted into brick equivalents. The report then considers that there are further requirements based upon repairs and rebuilding work, plus the housing plans in the "... 4th-6th Governorates etc.". The total demand was calculated as being 10 to 15 million bricks per year but this was qualified (page 15) where it is stated:

> "Recently, however, it has been clarified that so much demand doesn't meet the present conditions. From the above it will be a best way to construct a factory capable of sufficing the required quantity as a first step and in the event of demand increase in future, to meet the demand by two-shift operation upon expansion of part of facilities or to separately construct same capacity factory or newly plan a factory to the place in the vicinity of demand place."

The factory proposed by the Institute is based on an annual production of 12.5 million bricks. A cost/benefit analysis has been made in which it appears that full production, sales and income will be realized from the start of year one.

The Japan Consulting Institute has come to the conclusion that whilst brickmaking is technically feasible, the following qualifications, as interpreted from their report, have to be considered:

(a) The Jawala and Fiyush clays are high in Fe_2O_3, MgO and CaO. It is believed that the Fe_2O_3 is in the form of limonite whilst the MgO and CaO are in the form of sulphate and carbonate. The sulphate could give rise to scumming or efflorescence;

(b) Due to the uneven occurrences of clay and sand layers in the Jawala deposit, the more regular Fiyush deposit is recommended for exploitation. However, since less test pits were apparently dug at Fiyush than were dug at Jawala, this conclusion should be subject to further geological examinations. Both the German and Japanese tests have indicated that the actual clay fractions of both deposits are similar, i.e. apart from the regularity of occurrence;

(c) The clays have a relatively short vitrification range; firing should be within the range of 900°C to 1,030°C but, since this may not ensure full calcination of any carbonate present, a range of 1,000°C to 1,030°C has been recommended. At higher temperatures rapid vitrification takes place;

(d) After adding water to the clay materials, they must be aged for a period of more than 2 to 3 months. The purpose of this is to develop better extrusion qualities in the material, but it means that substantial storage facilities are needed;

(e) Floor-tile production is feasible, but it has been recommended that this be delayed until the brick factory achieves a stable production.

The cost of the proposed brick factory, including quarrying equipment, is given in table 1 of the report as follows:

"Table 1. Cost of construction and total investment

Item	Cost of construction (YD)	Operation fund (YD)	Total investment (YD)
Local currency	620,000	21,200	641,620
Foreign currency	2,430,000 (¥1,666,251,000)	165,380 (¥113,401,000)	2,595,380 (¥1,779,652,000)
Total	3,050,000 (¥2,091,385,000)	187,000 (¥128,226,000)	3,237,000 (¥2,219,611,000)

Exchange rates are based on $US 1 = fils 350 = yen 240."

The fact that the raw materials are considered to be somewhat problematic has contributed to the high cost of the factory, although, no doubt, international tendering would reduce this. Even so, with tunnel drying and firing as the means of exercising close control over the process, it will be highly capital intensive.

4. Study report concerning the manufacture of building materials in cold-processed crystallized clay, December 1984

This study was carried out by a joint ESCWA/AFMA mission. Essentially, the object of the study was to investigate the feasibility of industrialized production of bricks using a mixture of clay, Portland cement and possibly some additives to make a durable, low-cost building material. 1/ Testing of materials from Jawala and Mindara are said to have indicated that:

(a) The various levels of the deposit did not have to be separated;

(b) The full face of the quarry could be worked;

(c) The soils are not clays, but scawtites.

1/ The consultant has carried out development work during 1968-1970 on various soils and other materials mixed with Portland cement as a means of making low-cost building materials. The consultant has also, in 1984-1985, been engaged by UNIDO to develop a mobile brickmaking facility for the production of clay-based bricks which will either be burnt, sun baked, lime stabilized, or Portland-cement stabilized. The products will be extruded, and the first mobile facility has been made and will be shipped to Africa by the end of 1985.

The study report stated that the different soils:

"... have a deficient plasticity, but can be very easily extruded. Nevertheless their sensitiveness to water will require to be very careful with proportions of water in manufacturing."

On pages 25 and 47, with reference to Mindara and Jawala respectively, the following is stated:

"It should be noted that the soil (from Mindara/Jawala) is not very plastic; this gave rise to some defects in laboratory extrusion, owing to the inadequate power of the laboratory extruder and to insufficient vacuum."

In the conclusions on page 55 of the report it is stated that:

"The two soils are very similar. They are not clays but their extrusion does not present any difficulties ..." ... "The two soils are water sensitive, and the amount of water added needs to be carefully controlled."

With the process under consideration, the production equipment is essentially the same as that required for a factory making burnt clay bricks, up to the point of the extruder and brick cutter. The difference then is that, with burnt clay bricks the next stages are drying and firing whereas with cement-stabilized bricks the next stages are curing and drying. The main savings are of capital cost for a kiln and fuel costs for firing, although this would be partly offset by the cost of cement. The climate in Aden is almost ideal to consider atmospheric drying.

The estimated costs for the factory are given as follows:

	YD
Equipment, c.i.f. Aden	252,000
Training and commissioning of equipment	74,000
Civil works, construction, vehicles	130,000
Total cost (10 tonnes per hour facility)	456,000

In the summary of basic data (page 63) the annual output is given as 35,000 tonnes and this is put as equivalent to 3,200,000 to 3,500,000 bricks. The report indicates that 60 per cent of this will be 400 x 200 x 200 mm bricks, i.e. 21,000 tonnes, which apparently represents 1.9 to 2.1 million bricks. Taking the lower figure of 1.9 million it would seem that the individual brick weight is 10.94 kg, giving a bulk density of 0.68 g/cm^3. It may well be unfair to make such calculations, but if they are anywhere near correct, it is doubtful if a brick of such low bulk density can be made with the materials in question, and, if it can be made, it would require automatic handling facilities after the brick cutter.

As with the Japanese report, there is no evidence that the proposed factory output is based upon a proper market survey. It has been presumed that the products will be sold to the public and private sectors.

The main questions regarding the report, apart from the aspect of market studies, are given below but it should perhaps be made clear that they are not criticisms. Rather, they are points upon which clarification is required:

(a) The process is said to be one of cold-processed crystallized clay, but the report indicates that the raw materials to be used are not clays;

(b) There appears to be some anomaly about whether the material will or will not extrude easily;

(c) It should be made clear what degree of perforations are expected in the bricks, since this influences the bulk density and the numerical output of the extruder;

(d) The actual production levels in the initial years should be indicated from the point of view of reasonable expectations considering the introduction of a mechanized technology which is new in Democratic Yemen. Cost/benefit analyses should then be based on this, taking into account the current real value of the dinar.

5. Order Verwaltung GmbH, Federal Republic of Germany

That company has made proposals for a factory to produce a range of products based upon chemically bonded sand. This does not come under the terms of reference of this report, which considers mainly clay bricks. However, the products include wall materials which could be alternatives to clay bricks, and any subsequent market or feasibility study should take this process into account (see annex I).

B. Mobile brickmaking facility

The second handwritten report left with the Ministry of Industry and UNDP concerned the possibility of using a mobile brickmaking facility (MBF) as a means of making various types of bricks, possibly in different parts of the country according to specific needs. It is not intended to reproduce that document here in full, but rather to summarize the possible advantages and disadvantages of such a facility.

Mobile brickmaking is not new in that there are recorded examples in history where brickmakers travelled to make bricks wherever there was a market for their product and a need for their skills. Even today, at least in parts of Africa, there are brickmakers who travel hundreds of kilometres to make bricks close to the market, returning home when the brickmaking season has ended. In the modern context, mobile brickmaking as it is used here, involves a mechanized facility which operates from the back of a trailer or trailers and can be towed from one location to another.

The economic advantages of the MBF are normally related to savings in transport costs where bricks or other building materials would have to be carried over substantial distances. There are, however, other advantages where small population centres could not justify the production of bricks on a mechanized scale. This could apply to many rural areas, fishing villages and perhaps to the island of Socotra. Since the climate in Democratic Yemen tends to be arid, it may be possible to make a supply or stock of bricks in one location and leave the bricks behind to be used as dried (or fired) over a period of time, while the MBF would move on to another location as soon as the extruder has made the requisite number.

The main disadvantage of an MBF is that there is production lost during the various activities associated with moving from one site to another. This can be offset by economies elsewhere and in any case may not amount to more than 5 per cent per year if only two or three changes of location are made in each year.

The MBF would produce bricks which could be sun baked, lime or cement stabilized, or burnt. This assumes that the raw materials are available for such production, as with any normal brick factory. The bricks from an MBF would likely be extruded (pressed bricks are possible) and there is no reason why the mixing section could not be used to mix clays for other producers of sun-baked bricks, i.e. as a subsidiary operation.

Of particular interest could be the use of an MBF as a pilot/training facility to prove the viability of raw materials prior to the establishment of a larger brick factory, and as a training ground for personnel. Once this function would be completed, the MBF could either be incorporated into the larger factory or moved to a new location where there was a need for bricks.

As with any building materials production, it will be necessary to establish raw materials deposits first, in terms of quantity and quality.

In the event that the Government of Democratic Yemen requires further detailed information on mobile brickmaking facilities, it is recommended that UNIDO be contacted for advice.

C. Al Mukalla and Saywun, Governorate of Hadramout

Background

At the beginning of the mission it became clear that the question of establishing a brick factory had to be viewed against the broader background of the function that such a factory would have as a supplier of building (wall) materials in competition with or complimentary to the production of other similar materials such as concrete products. An early recommendation of the consultant was that an in-depth market analysis be made with comparative cost/benefit analyses, so as to enable the Government to take optimum decisions leading to an efficient development of the building materials industry, whilst taking into account such factors as raw materials supply, utilization of existing facilities and skills, factors relating to the building trades etc. Since such a study would consider various building materials and their use in probably five or six main population centres in the country, it was considered essential that the consultant see at first-hand at least two centres where different building materials and construction methods were used.

The two centres chosen for further examination were Al Mukalla and Saywun, both in the Hadramout Governorate but about 300 km apart. It was agreed to by the Ministry of Industry, UNDP and UNIDO, that the consultant could extend his stay by one week in order to be able to visit both places. Since the agreement for the extension was only received on 12 November 1985, the actual visits to Al Mukalla and Saywun commenced on 16 November. The consultant returned to Aden on 19 November and left the country on 20 November 1985. Throughout the visits the consultant was accompanied by an official of the Ministry of Industry who made the various arrangements for the journey and for meetings with government officials and other personnel.

Al Mukalla

Al Mukalla is the second largest town in Democratic Yemen and the administrative capital of the 5th Governorate (Hadramout). It is located some 500 km from Aden, connected by an asphalt-surfaced road. It is also the second largest port and the facilities there have been recently modernized. There are air links with Aden and internationally through the nearby Ryan airport.

Discussions were held with the Ministry of Industry, the Ministry of Construction (concrete block and brick factories) and the Geological Survey Department. Visits were made to the gypsum factory at Ghayl Ba Wazir, factories producing concrete blocks and bricks, and a quarry where cut limestone blocks and slabs were being produced. Private sector gypsum and lime producers were seen near Ghayl Ba Wazir and Halla (Shimousa) respectively. In the former case small bee-hive shaped heaps of gypsum were calcined in the open, whilst at Shimousa larger, conically-shaped intermittent shaft kilns (up to 8 or 10 metres high) were being used to calcine limestone. With the exception of one small lime kiln which used waste oil, the other kilns were fired with wood.

Al Mukalla and the surrounding area is characterized by multi-storey buildings (average about three storeys) constructed of building stone, concrete blocks, concrete bricks, or mixtures of all of these. Public sector buildings in particular utilize a reinforced concrete frame with infill panels of bricks or blocks. Foundations are made of dressed limestone blocks with crushed limestone being used in the sub-base. It was said that sandstone blocks had been used in the past but that the quarry was now worked out at surface level. Some other details given by a quantity surveyor were the sizes of:

Concrete blocks	400 x 200 x 220 mm
Concrete/sand-cement bricks	250 x 120 x 70 mm
	200 x 100 x 70 mm

When tested for compression strength the blocks were required to take a total loading of at least 23 tonnes. Elsewhere, it was said that such testing only took place about every three months but it was not possible to verify this. Various costs were given as follows:

	YD
Crushed limestone for foundations, delivered Al Mukalla	2/m^3
Larger crushed limestone, before dressing	4/m^3
Crushed stone, for foundation	45/m^3
Limestone walls, 600 to 800 mm thick	50/m^3
Hollow-block walls, 100 mm thick	9/m^2
Hollow-block walls, 200 mm thick	13/m^2
Plastering	4.5/m^2
Concrete bricks, delivered Al Mukalla	70/1 000
Portland cement, at Al Mukalla port	50/tonne

With respect to reinforced concrete, an architect said that a major problem was corrosion of the reinforcing steel leading to physical depreciation or spalling of the concrete. This problem had also been mentioned in Aden as one which affects concrete along the coastal area. In the coastal region it was said that the mean summer temperature is 37°C; surface temperatures rise in excess of 50°C and there are day-night differences of about 25°C. These conditions coupled with high relative humidities are conducive to rapid corrosion of unprotected steelwork.

With respect to deposits of brick clays, there was no information available and the senior geologist in charge of the geological survey at Al Mukalla was said to be in Aden at the time of the visit. Buildings of sun-baked clay were not evident in the area, but a minaret near the harbour was said to be made of that material.

Saywun

Saywun was reached by road from Al Mukalla after a journey of about 5 1/2 hours which included half an hour at the old and historic town of Shibam. The town of Saywun is also in the 5th Governorate and is the administrative centre of the Hadramout Valley (Wadi Hadramout).

Due to difficulties in getting transport from Al Mukalla, Saywun was reached after dark and it was not possible to have discussions with officials there. However, part of the town was seen at 6 a.m. on the following morning on the drive to the airport. More importantly, the road down through Wadi Ain and Wadi Hadramout has many villages (including Shibam) featuring multi-storey houses constructed almost entirely from sun-baked clay bricks on stone foundations. It would, perhaps, require a poetic rather than a technical description to do justice to the variety of mosques, houses and other buildings.

Shibam itself is over 500 years old with buildings up to about eight storeys, constructed entirely of sun-baked bricks. One old building which had been demolished appeared to have a foundation of rough or undressed stone, bonded in clay. The original clay bricks had been broken up and mixed with water to be used again after moulding and drying.

Clay is not only used for wall construction, but also for roofs and ceilings. A number of such ceilings were seen, embossed with a variety of designs painted in different colours. It was not possible to say from visual observations that the ceilings were made from clay and without having been given the information they may have been taken for "normal" ceilings.

Throughout the journey from Wadi Ain down through Wadi Hadramout there was much evidence of sun-baked clay bricks being made and of much construction taking place. The bricks (technically they could be called tiles, being 450 to 550 mm long, about 350 mm wide and about 60 mm thick) are made of silty clay with straw and manure, mixed with water, moulded on the ground and allowed to dry in the open air. Several foundations for new buildings were seen, comprising a low stone wall, apparently jointed with mortar and filled with broken stone to above the wall level as a basis for the floor.

In marked contrast to Al Mukalla, there were few if any all-stone or concrete buildings seen. In this context it should be understood that not only was the visit a short one, but it is usually difficult to tell what is under the exterior plaster. All the houses seen were noticeably of mud-brick construction or, if plastered, were said to have been of this type of construction. Supporting pillars, e.g. of verandas, were said to have been made of clay bricks in the past, but now stone and clay were used. Again, it is almost impossible to tell from a purely visual examination.

D. General observations

In discussions held with an engineer at Aden Municipality it was said that there were still many bricklayers who had worked with bricks as opposed to the larger blocks. However, it may be expected that these skills will disappear with time, i.e., the skills of bricklaying as opposed to blocklaying.

In discussions with representatives of the cement factory project it was said that the factory should come on stream late in 1988. The designed capacity is 350,000 tonnes per year, but in the first three years it was anticipated that the output would be about 60 per cent of this. They held the

view that the market survey for cement may have under-estimated the real import levels, but no documentary evidence of this was available at the time of the relatively unscheduled visit.

At the Geological Survey Department the Deputy Director said that there was no special programme at present to define useful deposits of brick clays. The survey was concentrating on a nationwide programme of geological mapping. It was anticipated that the western part of Democratic Yemen would be completed by 1988. Occurrences of clays would be noted as part of this wider survey. However, the deposits at Lahej had been examined and a more detailed exploration would start in 1986.

The Survey Department is only about 10 years old and there is a continual need for expert advice in various areas. At present, assistance is being given by specialists from Czechoslovakia, German Democratic Republic and the Union of Soviet Socialist Republics. The Department has about 80 engineers specializing in all aspects of earth sciences. The laboratory carries out chemical analyses of clays as required, but physical testing is carried out by the Ministry of Construction. The report of the Japan Consulting Institute did not appear to be available in the Survey Department. In fact, it was sometimes found that other reports might be available in one place and not in another where there was a related interest in the results and recommendations.

Two meetings were held in the Ministry of Construction and some field trips made with a geologist from the Ministry who subsequently went on a short fellowship to France to further examine the "cold-processed crystallized clay" developments at the laboratory which did the test work for the study.

The laboratory at the Ministry of Construction is a general materials testing laboratory which, with some further items of equipment could carry out a wide range of tests on clays. However, there is a need for practical experience in such testing and more particularly in the evaluation of results. A list of some equipment items which would prove invaluable in clay testing is attached to this report as annex III. Annex IV contains some technical books which should be of use to the various ministries and departments dealing with brickmaking and clay testing.

The Ministry of Construction is concerned with the high cost of construction and is examining ways in which this might be reduced, including the needs for lower-cost building materials. In this respect, the market and techno-economic study proposed in this report should provide information that is of use to the Ministry of Construction as well as to the Ministry of Industry and the Geological Survey Department.

III. CONCLUSIONS

There has been no in-depth, market-related techno-economic study made with respect to the brickmaking industry as such. Since the production of bricks is simply a sub-sector of industries supplying wall materials, any such study must consider other wall materials. The overall objective of the study which has therefore been proposed is to enable the Government to plan and subsequently to implement a programme of wall materials production which best serves national needs. The study would logically take into account economic, social and environmental factors, government plans and the capacity to maximize the use of local personnel, raw materials and existing investment. The options for further development of such existing investments and the related expertise which has been developed, must be compared in a realistic and detailed manner against any proposals for new investments (see annex I).

The clay deposits of Fiyush, Jawala and Mindara have been examined in some detail by various professional bodies. The universal conclusion is that whilst clay bricks (burnt clay or cement bonded) can be made, close control is required at all stages of the production process. The implications are that substantial capital investments are required in terms of plant and equipment if perforated blocks have to be made but a lesser investment might be required if only (smaller) bricks are to be made. In both cases, a reasonably high degree of management, technical and maintenance services must be available or developed to an adequate level.

The process called "cold-processed crystallized clay" has much to recommend it, although the term "cement bonded" is considered to be a much more understandable descriptive name for the process. This process avoids the importation of fuel, although there is obviously a fuel component in the Portland cement which is used. It is not yet clear if chemical additives will be necessary, but if so, they too may have to be imported. It should be understood that a well-made burnt-clay brick or block would have a wider range of superior qualities than would cement-bonded bricks or blocks. However, as indicated in the chapter I, "Background" of this report, it is the adequacy of a particular product for the intended job which should be used as a measure of suitability, and on this basis the cement-bonded product should have a wide application. It has not been seen that the study already carried out is sufficiently conclusive in confirming the suitability of the raw materials. Even with such confirmation it is considered that the proposed market-techno-economic study must be completed first to permit the Government to make the best choice.

As mentioned before, the country's first factory to produce Portland cement is scheduled to come on stream late in 1988. It has a designed capacity of 350,000 tonnes per annum, but in the first three years of operation that output will be 60 per cent. If there is a surplus of production over demand, there may be some pressure to develop wall materials based upon Portland cement. This may not be a long-term consideration. On the other hand, diversifying away from cement-bonded products may give some safety margin by providing alternate materials which are not totally dependent on cement for their production.

The ability of the Materials Testing Laboratory of the Ministry of Construction should be developed to carry out at least basic clay tests. Some further items of equipment have been suggested to this end, but these can only be justified if the essential personnel get some training in clay testing and, especially, in the evaluation of results.

A mobile brickmaking facility has been suggested as one possibility to enable machine-made products to be made in centres which because of their small size could not otherwise justify a mechanized facility. Any decision on this should be related to the examination of other options following the proposed market and techno-economic study.

There is a variety of building materials being used in the Hadramout Governorate, many of which are made from purely local raw materials. Reinforced concrete as used there and in other coastal areas is giving problems associated with corrosion of the reinforcing steel. On the other hand, buildings constructed purely from sun-baked clay can have problems related to leakage from reticulated water or sewage. The proposed market and techno-economic study should point to those areas where, at least for the public sector, some development can take place to solve these problems.

The Geological Survey Department has a heavy workload and can hardly be expected to satisfy every request for information immediately. However, there is an urgent need to establish, at least for Aden, the detailed locations, quantities and qualities of raw materials for the building materials industries. UNIDO may be able to assist with specialized help, at least in the field of non-metallic industries, if specific requests are made.

Annex I

TERMS OF REFERENCE FOR A TECHNO-ECONOMIC FEASIBILITY AND MARKET STUDY FOR THE PRODUCTION OF BUILDING (WALL) MATERIALS IN DEMOCRATIC YEMEN

A. Preamble

Democratic Yemen occupies a territory of 208,000 km^2 of the south-western corner of the Arabian Peninsula, with a coastline extending from Bab el Mandab in the south-west to the borders of Oman on the Arabian Sea in the north-east. The population of the country is 2.06 million.

Aden has the largest port in the country, followed by that of Al Mukalla which has been undergoing modernization and where the new docks of Khalif harbour are due for completion in 1985. Aden has also the busiest airport, again followed by Al Mukalla (Rayan airport) which is second busiest in terms of air traffic. Within the country, the major part of goods is transported by land. Asphalted roads joining Aden to Al Mukalla, with extensions eastwards and branches to interior Hadramout, are the busiest. The distance by road from Aden to Al Mukalla is 625 km.

Through successive development plans, the Government of Democratic Yemen is furthering the industrialization of the building materials sector, with the aim of replacing imported materials and of serving the growing building industry. However, traditional building materials are not being ignored, and should the study show that such materials are preferable to others, their production by improved methods will be encouraged.

A number of studies relating to raw materials and technology, and with varying degrees of economic considerations are available. As yet, no in-depth study has been undertaken which compares the relative benefits, on a national scale, of one type of production to another, and recommends certain products or product ranges which should be promoted for the national benefit.

A consultant, engaged by the United Nations Industrial Development Organization (UNIDO) under the project UC/PDY/83/133, has in November 1985 assessed some technologies, based on technical reports already available. He, however, pointed out that a combination of technical and economic information, based upon an in-depth market study, was essential to make optimum predictions. This study should complete the range of prior activities and indicate to the Government the values of the various options for development of the building (wall) materials industries.

B. Background

Definitions

Building (wall) materials, for the purposes of this document, shall comprise the following:

(a) Clay-based products, including sun-baked bricks, lime-stabilized bricks, cement-stabilized bricks and burnt bricks;

(b) Sand-based bricks using lime, cement or chemical bonding agents;

(c) Concrete bricks, prefabricated panels and building stone.

The term "brick" shall refer to what are conventionally known as bricks as well as to blocks.

"Solid bricks" shall refer to those in which the volume of perforations, cavities or indentations is 25 per cent or less of the gross volume of the unit.

"Hollow bricks" shall refer to bricks in which the volume of perforations, cavities or indentations exceeds 25 per cent of the gross volume of the unit.

Previous reports

Whilst the consultant(s) shall liaise through the Ministry of Industry in obtaining information from other government or private bodies, the following reports in particular should be considered:

(a) Research report for clay bricks and wall tiles, EKEA Aktiengesellshaft, D-7500 Karlsruhe 41, Greschbachstrasse 23, Federal Republic of Germany (October 1978);

(b) A review of the construction and manufacturing sectors, World Bank Report No. 3669 - YDR (30 October 1981);

(c) Report and proposals from Order Verwaltung GmbH, Gralibeton, Kaiserhofstrasse 16, D-6000 Frankfurt a.M., Federal Republic of Germany;

(d) Tender-offer for the supply and installation of a factory to make 25 million bricks and 100,000 m^2 floor tiles per year. "Pragoinvest"- Foreign Trade Corporation for the Export and Import of Machines, Machinery Equipment and Complete Plans, P.O. Box 12, Praha 8, Czechoslovakia, (reference 316/908/77, code 316/4440, June 1978).

Note: That offer was not based on detailed raw materials studies;

(e) Report on the feasibility of clay brick manufacturing plant in the Peoples' Democratic Republic of Yemen, Japan Consulting Institute (March 1978).

Note: That report is not considered to be a complete feasibility study except where it considers the technical feasibility of making burnt clay bricks and tiles;

(f) Study report concerning the manufacture of building materials on cold-processed crystallized clay, joint ESCWA/AFMA mission (December 1984).

Note: The process referred to is one whereby a mixture of clay raw material, Portland cement and possibly chemical additives are extruded to form bricks;

(g) Technical report of the UNIDO brickmaking consultant, project UC/PDY/83/133. That report is based on a three-week mission to Democratic Yemen in October-November 1985.

Brickmaking, i.e. burnt clay bricks, was previously carried out at Mindara, near Aden, where a simple extrusion process was used to make a solid brick. The bricks were air dried and fired in a Bull's Trench kiln. The factory ceased operating around 1976.

Sun-baked bricks are made in many parts of the country, often as a small-scale family operation. In Hadramout there is a long tradition of building with such material. This, combined with a high degree of traditional

architectural and building skill, has led to the construction of multi-storey buildings dating back at least 500 years. At Al Mukalla and Saywun (in the Wadi Hadramout) there is also a long tradition of using lime and limestone bricks. There are good deposits of lime in these areas as well as gypsum near Al Mukalla.

Near Aden, at Mindara, Fiyush, Jawala and Suffian Lahej there are extensive clay deposits. Laboratory tests have indicated that, whilst the process must be carefully controlled at all stages, it is possible to make burnt clay bricks and possibly tiles. There are other clay deposits in the country, including one of kaolinite, but except for the clay to be used in cement manufacture these deposits have not been studied in great detail. A study of the geologists' reports will be necessary.

A Portland cement factory will be constructed some 90 km north-east of Aden. It is expected to come on stream late in 1988 with a design capacity of 350,000 tonnes per year. Currently all Portland cement is imported.

There are a number of public sector and small-scale private sector producers of concrete blocks. At Aden there is a factory producing precast concrete products and relatively light-weight panels. There are serious problems with reinforced concrete products near the coast where corrosion of the reinforcing steel causes physical depreciation of the concrete. Sawn limestone blocks and panels are being produced near Al Mukalla.

C. Objective of the consultant services

The Ministry of Industry of Democratic Yemen wishes to consider the specific options available for the upgrading or expansion of its industry to produce wall materials in the main population centres of the country. This necessitates an investigation into the building materials industry as such, but does not preclude the need to examine the non-metallic minerals industry which supplies the bulk of raw materials, the building industry which uses the products, and other areas which have or will have significant influences (alternative wall materials, imported process needs etc.).

This investigation shall include an examination of existing reports, as indicated in section B, "Background", as well as such other reports as are available and pertinent to the investigations and subsequent analyses.

The report shall include specific recommendations for the establishment of building materials production facilities, including a cost/benefit analyses of a realistic nature, a detailed description of the technologies to be employed, the range of products to be made and the reasoning behind such proposals, and the specific locations for production to be established, including calculations showing why and how those conclusions have been reached. Based on a study of existing production facilities, the report will indicate if and how these might be realistically improved or expanded to meet the demand and/or to reduce the cost of production. The consultant(s) shall indicate if and how local resources of technical expertise and facilities can be utilized to carry out further studies which may be required, e.g. an evaluation of raw materials deposits. Further data on this and other requirements are detailed below.

D. Scope and sequence of tasks

Stage 1

Raw materials

A consultant in heavy-clay technology shall examine the results and conclusions of previous reports relating to raw materials occurrences, their qualities and utilization or potential utilization, to confirm (or otherwise) the sufficiency of work done and the conclusions which have been drawn. The recommendations shall include precise and sufficient documentation which can be used for tendering for any additional geological and subsequent laboratory work. Where possible, such work will be done in the country.

Taking into account the results of the market study and based upon the proven or calculated potentials of the raw materials, the consultant shall recommend which technologies can be used to make the recommended product range(s). This shall include details of the plant and equipment for quarrying, comminution and pre-treatment of raw materials, in-plant processing, through to the stocking of the finished product.

Market

In considering the market for the defined building materials, the consultants shall consider the following, as well as any other items upon which prior agreement has been reached with the Ministry of Industry:

(a) Domestic production in the main centres;

(b) Imports;

(c) Comparison of prices and uses of imported versus domestic products;

(d) Requirements for quality, e.g. conformity to size and shape, strength, durability, low-cost buildings, special projects etc.

(e) Comparison of domestic and imported wall materials with which proposed production might compete in the future, replace or complement it. With reference to domestic products currently being produced, it is not the Government's intention to replace them if their production can be justified;

(f) Estimate of trends in domestic products, imports, and construction where the defined products are being or will be used. The estimate should include trends in prices, volumes, and if possible local manufacturing costs;

(g) Estimate of population and per capita income growths and, based on this, consumption trends. Remittances from migrant workers and their future prospects in terms of world economic trends should be taken into account;

(h) Estimate of market share of proposed products in the designated main population centres;

(i) Determine which part of the market any proposed product will serve and which part cannot or should not be served, indicating the reasoning behind the determinations;

(j) Estimate the costs "in the wall" for the proposed products versus those for existing products, and quantify, as far as possible, other benefits which may or may not be of a direct economic nature such as internal or external environmental factors;

(k) Determine the main purchasing groups and indicate how best the proposed products can be marketed;

(l) Indicate how and to what extent improvements can be made with respect to existing products (e.g. quality, product range, efficiency of production);

(m) Evaluate and report on needs relating to the upgrading of skills in the building industry so that the proposed products can be efficiently or more efficiently used. This might include designers, builders and artisans, and should in any event detail how the problems of lack of skills can be overcome.

With respect to traditional products such as sun-baked bricks, the study should consider that low-quality, low-cost, but otherwise adequate products (in terms of end use) may compete more than favourably with improved equivalent products, e.g. machine-made sun-baked bricks, purely on the basis of selling price or installed cost.

Based upon the above considerations the consultants shall evaluate the alternatives for the building materials industry, while ensuring that it should best meet predicted demands and taking into account raw materials, technology, skills and government objectives.

Stage 2

This stage shall commence after finalization of stage 1 and following consultations with the Ministry of Industry.

The consultants shall contact manufacturers and suppliers of the equipment items or systems covering the various proposed technologies to obtain budget prices for (a) supply and (b) installation (where relevant) of the equipment. Also required are estimates of the shipping and insurance costs to the relevant port in Democratic Yemen. The information from the potential suppliers shall also indicate related requirements such as details of buildings or other structures. foundations, power supply and any other special requirements.

Raw materials

For each case, the consultants shall specify the equipment requirements for excavating, quarrying or otherwise winning the raw materials from the ground, including such equipment as is necessary to transport the raw materials to the factory and for any intermediate processing stages. The specification shall be in sufficient detail and in such a form that it can be used as the basis of a call for tenders.

The consultants shall advise upon realistic alternatives for returning exhausted quarries or excavation sites to productive use, e.g. for agriculture, silviculture, fish ponds, water storage etc. The advice should indicate if and how this might be done on an incremental basis, e.g. annually.

Plant capacity and production programmes

The production programmes, assuming different or at least separate programmes for each of the designated population centres, shall be based on the results of stage 1. The market analyses and the range of products which can be reasonably made, taking into account the raw materials, shall be the main determining factors in the selection of the production programmes.

The study shall include a detailed discussion of the factors affecting the choice of product mix, or products, or the upgrading of existing facilities, as appropriate. Where a pilot plant should be established to prove technical viability or to serve as a training unit, all requirements should be indicated in similar detail as for a full-scale production facility.

Plant capacities shall be discussed based on clear indications as to:

(a) Present optimistic and pessimistic demand estimates;

(b) Realistic estimates of actual output as a percentage of the designed capacity. This should also be taken into account in any cost/benefit analyses;

(c) Future increases in demand and options for expanding output;

(d) Possibilities for future diversification of production and steps which might be taken now or from the start of operations, to capture a larger share of the market in the future (e.g. development of and marketing strategies for new products).

Alternative technologies should be discussed and recommendations made regarding the choice of technology. The criteria for selection should be given and these shall include consideration of the following:

(a) Investment costs;

(b) Operating costs, including maintenance;

(c) Suitability to local conditions;

(d) Durability and reliability;

(e) Ability of the building industry to utilize the products.

Raw materials or additives to be imported for any of the proposed technologies shall be discussed, giving details of potential suppliers or sources of supply, prices and any present or future possibility of providing or making them in the country.

Locations an 's

The selection of locations shall be subjected to detailed discussion, and the comparisons of advantages and disadvantages between the various options should be made explicit. Similarly, the selection of a site within a location should be discussed in terms of requirements and advantages.

Any additional requirements to be provided shall be referred to in detail.

Engineering

The consultants are expected to include in the report a general plan of the site(s), buildings and facilities. Types of buildings to satisfy special requirements, such as technical, safety etc., should be clearly described. The consultants shall compare variants of buildings and building material, e.g. concrete, prefabricated steel structures etc., and recommend the most suitable ones.

Services within the factory for provision of process requirements such as compressed air, vacuum, treated water, electric power, storage and handling of

fuel etc., should be discussed in sufficient detail to satisfy the purposes of the study and also for negotiating and contracting for the supply and delivery of constituents. Alternatives should be compared and the best recommended.

Concerning external handling and transportation, existing and recommended additions of infrastructural facilities for transportation should be discussed and the various alternative transport facilities compared.

Various technologies should be reviewed, giving detailed descriptions for each type of technology with flow diagrams and material balances. The alternatives of using whole packages or parts should be analysed and compared, giving the optimal set-up consistent with the local conditions, minimized investment and operating costs, good products quality and durability of the plant.

For the production equipment the main units should be listed and described in detail.

Special technical know-how and similar issues should also be examined.

Company and factory organization shall be discussed in detail and organization charts provided in the study. The manpower requirements shall be stated by categories and section-wise. Training and expertise requirements shall be indicated with advice as to sources.

Project implementation

For any major production facility, investment planning should be based on a realistic work plan. This shall include recommendations on the selection of contractors and forms of engagement, i.e. turnkey or otherwise.

Financial and economic evaluation

The consultants shall prepare the following (including detailed justification thereof):

(a) Capital cost: Estimates for each project, including deposit beneficiation. The estimate(s) shall be broken down into production units and major components. Allowances for price and physical contingencies shall be calculated as well as interest on investment during construction and other pre-operational expenses. Costs of investment in local and foreign currency shall be shown separately;

(b) Working capital: To be calculated on the basis established after discussion of costs, storage periods and other related considerations.

(c) Financing: The consultants shall investigate possible alternatives of financing the project(s) and shall advise on the most recommendable package.

(d) Financial feasibility including:

(i) Financial plan and disbursement schedule;

(ii) Production costs by categories to be tabulated as a whole, showing fixed and variable costs;

(iii) Financial performance under projected financial conditions, showing projected financial statements (income statements, cash flows and balance sheet) for the life of the project(s). The financial analyses should include:

- Rates of return (simple and internal, both economic and financial)
- Payback period
- Debit service coverage ratio
- Changes in working capital
- Net present value at interest rate of long term loans in world market capital market;

(iv) Sensitivity analyses:

- Effect of production levels
- Effect of sales prices
- Effect of operating expenses
- Effect of capital cost over-runs;

(v) Risk analyses: Identify the risks and suggest remedial measures;

(vi) Competitive analyses:

- Comparison of capital and production costs with major competitive (producers) sources .
- Competitive position under current conditions including consideration of technical, economic and other factors.

Socio-economic analyses

The consultants shall also calculate the indicators in (d) above on a socio-economic basis.

Further, the consultants shall calculate the following:

(a) Added value, where relevant;

(b) Effect of project(s) on foreign exchange.

E. General

The feasibility study shall comply with the criteria laid down in the Manual for the Preparation of Industrial Feasibility Studies (ID/206, United Nations publication, Sales No. E.78.II.B.5) and shall satisfy the requirements of international financing institutions.

Sources of information shall be indicated and major assumptions should be avoided unless absolutely essential and justified.

Possible difficulties in implementation, management and operation of the project shall be identified and recommendations made for plans to overcome these.

The consultants shall prepare and submit the following reports:

(a) A draft report for stage 1, in English. This draft report shall be discussed with the representatives of the Ministry of Industry, and based on the results of these discussions "agreed minutes" shall be signed by the Ministry and the consultants in which the further work to be done shall be clarified;

(b) A draft report in English for stage 2. This will be subjected to discussions between the Ministry and the consultants resulting in a document of "agreed minutes";

(c) A final report, covering stage 1 and 2, duly modified to comply with the two documents of "agreed minutes" referred to above, in English. This final report shall be submitted to the Ministry of Industry at Aden.

Annex II

PRINCIPAL CONTACTS DURING THE MISSION

Ministry of Industry

Taha Mohamed Shaker, Assistant Deputy Minister for Investments
Omar Orabi, Deputy Chief of Department of Industrial Studies
Awad Saeed, Head of Feasibility Studies Section
Abdul Wahed Abdulla, Building Materials Projects
Saiid Awar Baisa, Officer in Charge, Hadramout Branch

Ministry of Construction

Alawi Zair, Assistant Deputy Minister of Construction
Ali Shaiif, Geologist
Ahmed Ali Murshid, Head of Laboratory Section
Abdulla Ganem, Aden Municipality
Deputy Manager, Precast Concrete Factory, Aden

Al Mukalla - Brick and concrete block factories, engineering and quarrying:

Mohamed Abubaker Bel Fagih
Ahmed Saiid Sheber
Ahmed Saiid Bantar
Saiid Salla Bel Affir
Ahmed Mohamed

Geological Survey Department

Ahmed Shiek Baabad, Deputy Director

Cement factory project

Fuad Abdul Karim, Deputy General Manager
Fassal Ahmed Mohamed, engineer

United Nations Development Programme

Taoufik Ben Amara, resident representative
Ismail Mohamed, junior professional officer
Eduardo Bayon, UNIDO project manager (DP/PDY/81/006)
Ahmed Sedky, UNIDO project (DP/PDY/81/006)

Annex III

SUGGESTED EQUIPMENT FOR THE MATERIALS TESTING LABORATORY OF THE MINISTRY OF CONSTRUCTION

Laboratory extruder, 75 mm diameter barrel, with dies to make a range of solid and perforated samples

Laboratory thermal gradient furnace, top temperature 1,200°C, with cam-activated controller and multi-point temperature recorder

"Barrelattograph" to measure linear change and weight loss during drying of clay specimens

Annex IV

SUGGESTED TECHNICAL LITERATURE

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