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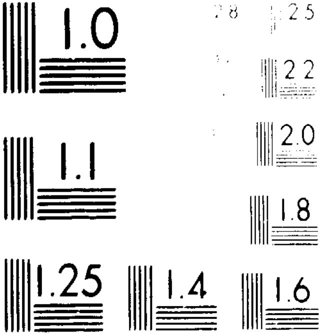
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Final Report

Project Number: SI/JAM/81/802

Project: JAMAICA - Pilot scale testing of representative samples of bauxite residues /red mud/ for profitable utilisation in the building materials industry.

Sub-contract: Result of pilot scale testing and adaptation study.

Prepared by: F. Juskás, ceramic expert and
A. Geszti, project coordinator

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Acknowledgements

The authors wish to thank all those who helped them in their work and made this report possible: Dr. Balázs and officials of UNIDO, Dr. Davis and officials of JBI, SRC, JNIP, JIDC in Jamaica, experts and officers of the companies Dorst, Ferro, Riedhammer, [illegible], Händle and Keller.

Chapter One

Executive Summary

Following a recommendation from UNEP, the Jamaican Government requested assistance from UNIDO in establishing the technical and commercial feasibility of adapting a proprietary method of red mud utilisation for the production of building materials, elaborated by Mr. F. Puskás.

Based on a field trip, laboratory tests and a subsequent pilot-scale production demonstration using red mud and various mineral additives, all of Jamaican origin, the following findings have been made and are reported in greater detail in this report:

1/ Red mud from the current production of at least one of the alumina producers /Kirkvine/ and local mining products can be combined in formulas to yield products with acceptable to excellent quality parameters. Possible products include glazed and unglazed tiles, roofing tiles, bricks and building blocks. Red mud content of such products range from 50 p.c. /tile/ to about 80 p.c. /building block/. Present production and red mud discharge practices of alumina producers need not be changed.

2/ Considering the size of the Jamaican building materials market the amount of red mud that can be utilized seems to be ultimately limited to some half a million tons a year, although additional products could be indentified by further work. Size of new processing capacities will be initially limited by the investment capital available.

3/ As energy typically accounts for 20 to 35 p.c. of total production cost of individual types of ceramics products, the economic feasibility of a ceramics project will be largely influenced by the choice and price of fuel..

4/ Red mud building blocks and bricks can be produced using either local fuels or imported coal and the cost of such production will allow the initial capital outlay to bring reasonable returns provided that fuel is bought at world market prices and plant is established under the Industrial Incentives Act.

5/ Semi-industrial scale production test proved the possibility to produce excellent quality glazed floor and wall covering tiles from Jamaican red mud and mineral additives. It is proposed that a tile plant be built to initially produce two to three million sqft/year glazed wall tiles, glazed floor tiles, roofing tiles and similar products. This venture would require about US $ 2.3 mn and J$ 3 mn in financing. With little competition from others in the region Jamaica is in an excellent position to become the major tile supplier to the Caribbean Countries and to the Southern and Eastern U.S. and Canada. Provided energy is available to the plant operator at world market prices, cost of the red mud based product produced in Jamaica can be sufficiently low to permit flexible marketing strategies to be used in exports.

6/ It is recommended that the Government of Jamaica encourage a red mud based ceramics industry to be established in Jamaica.

As there is neither a large scale tile nor brick production in Jamaica, it would seem reasonable to evaluate any such future project for its contribution to red mud utilisation, and use results in a decision about subsidies, etc.

Chapter Two

Project Background and History

2.1 Project Background

The method to produce aluminium by electrolysis was invented by the French Héroult and the American Hall in 1886. The technology of alumina production was patented by the Austrian Bayer in 1892.

Over the past 100 years the production and industrial use of aluminium have risen from an annual quantity of a few hundred tons to 15 million tons on a global scale. To produce unit quantity of aluminium requires twice that amount of alumina. The Bayer process yields 1.2-1.4 tons of red mud per alumina tons, i.e. not less than 40 million tons of red mud is produced in the alumina factories of the world every single year.

While production figures ran low, the disposal of red mud in mud ponds was no great difficulty. Specialists were confident that by the time red mud disposal was to become a headache for them feasible methods to make the best use of red mud would have been found.

Initial efforts to put red mud to industrial use lay in the direction of smelting, as was indicated by its high ferro-oxide content, which may run up to 40-60 p.c.

Efforts at smelting resulted in various patented processes but no industrially and economically feasible method has been found to date. Repeated economic analyses have proved that the pre-produce of iron ore substitute is non-competitive not so much because of its specific technological parameters as the high capital investment involved.

Up to quite recent times all efforts to find uses for red mud in large quantities have failed, and so this by-product keeps on accumulating year after year.

As is well known to specialists, the Bayer process, although the most successful method of alumina production known to us, has certain disadvantages. Furthermore its drawback stems from one of its fundamental technological phases that originally put it at an advantage over all other efforts in this direction. Notably, that ground bauxite is transformed at 100-280 C^{o}, at 6-80 kp/cm^2 with the addition of concentrated caustic soda into water-soluble sodium aluminate and insoluble Si, Fe, Ti, etc. compounds. The insoluble solid parts of bauxite processed with caustic soda are removed by filtering from the sodium aluminate solution, and this removed material is in fact what we call red mud. If the solid residue did not contain free caustic soda of an aggressive character as well as about 10 p.c. sodium oxide equivalent to bound sodium compound, then red mud would not at all be a hazard to the environment. However, the high amount of sodium it does contain makes red mud an ever-growing menace to fields, woods, meadows and river life.

It would be easy to find a way out if we could process bauxite with an alkali whose residue in red mud were no danger to the living world. Also, bauxite exploitation today can be accomplished with the help of acids and acidics coupled with an appropriate closed-system technology and alkali neutralization of solid mud remainders. However, it would be too early to regard these possibilities as a large scale, industrial solution to the problems outlined. However, it is rather likely that one of these methods - now at an experimental stage - will grow into the basic technology of alumina production and replace the Bayer process by the turn of the century.

Of course the quantity of red mud and the worries it gives us will continue to grow until that time. There is a certain limit to increasing the surface area of artificial mud ponds, which cost money to build, may tie up valuable farmland and which may be positively harmful over a much larger area than the pond itself, if a leakage of sodium solution occurs due to insufficient water insulation. If the sodium solution reaches ground water, rivers or lakes, it will become a hazard not only to plants but animals and humans as well. Some alumina factories try dumping the mud into the sea, a method that has provoked angry public response and is therefore radically discouraged by some governments. So the question naturally arises whether there is any good solution to red mud disposal.

A noteworthy technique of storing red mud has been developed by the German Gebrüder Guillini Co. After the sodium aluminate solution is seperated from red mud sludge, red mud is filtered in a drum filter, washed and chemically processed in a reactor called mixer, then processed with a flux material and finally, when the sludge has lost much of its water content, it is carried to the storing area by means of pumps.

Due to chemical processing, natural evaporation and the natural water balance of the storing area, the processed red mud soon loses its surplus water content and hardens so much that it can even carry heavy machinery. These kinds of red mud storing areas need no special water insulation because the water-soluble sodium salt content is below 0.5 p.c., so the danger to the environment is at a minimum. Red mud hardened by the Guillini process can be stored in waste-tips 25 metres high, therefore demand for ground area is reduced to one-fifth of that of traditional mud ponds.

As mentioned before, red mud consists of finely ground silicates, iron-hydroxide and other practically water-insoluble compounds as well as of residual caustic soda and other soluble salts. Recent decades have seen attempts to look at red mud as a finely granulated homogeneous additive material for the ceramic industry rather than a raw material for metallurgy.

The initiative was again taken by the German Guillini Co., and brick production has in recent years been successfully conducted in one factory in South Germany by the method they have developed and patented. The technology is as follows: Red mud is mixed with a hygroscopic material and a large quantity of clay, moulded into bricks by the traditional process, dried and fired at about 900 C^{o}. The mixture has a red mud content of some 40 p.c.

The Guillini bricks excelled clay bricks in quality, with special regard to strength, the former product was found 2 to 4 times stronger than the latter. It was established, however, that firing gets increasingly difficult with a rise in red mud content, and that the method was only successful in the case of red muds of low or medium ferro-oxide content.

More importantly, the economics of such a production proved to be insufficient to keep balance with the accompanying problems: For one thing, South of Germany is rich in cheap clay of excellent quality and most brick yards own their caly mine. There was little incentive for the brickmaker to replace his clay with red mud, especially as clay could not be replaced totally. Since the cost of mining doesn't scale well with decreasing quantity, the unit cost of clay to the brick company went up. On the other hand the brickyard would have to be very close to the red mud pond to prevent pollution problems from occurring and to keep costs down. Although no brickyard was close enough to the pond, competition coming from several dozen brickyards already operating in the area questioned the feasibility to set up a new one by the pond. As the authors learned from one of Guillini's top executives, now leading another company in the industry: one has to provide for a large value added, larger than in brick making, to get started with the utilisation of red mud. Although economics work in different ways in Germany and in Jamaica, this statement is probably valid in both countries.

On the basis of his previous experience in ceramics technology, one of the authors, Mr. F. Puskás, set out to develop a method to utilize large amounts of red mud in the production of ceramics. He described this method in a paper that was later awarded a prize in a contest "Utilization of industrial wastes" sponsored by the Hungarian Academy of Sciences in 1977.

The advantages of this method can be summarized as follows:

- A wide variety of products is now possible, including high value-added items such as glazed tiles and frost-proof porous products.
- More red mud /over 50 %/ and not just clay but many other materials some of them otherwise useless, can be used to make up the body /industrial residues containing silicates, volcanic products, rock material normally considered dead in quarry and ore mining, slag from a garbage incinerator, etc./.
- Alternative production methods can be used to sit the product and the available raw materials. Ease and low cost of production are key: low shrinkage during firing, fuel saving rapid drying and rapid firing can be applied readily.

The new method has been patented as an invention in Britain, Australia, the United States and a number of other countries. It was also treated in outline in a Hungarian document complied for a UNEP conference on environmental protection for the alumina industry held in Paris 20-23 January, 1981. The author was subsequently invited to the Paris conference, where his method won general acclaim and was incorporated into the list of recommendations adopted by the conference. Several delegations were interested in studies geared to their countries' respective conditions. It was the Jamaican government that first requested UNIDO to have a similar study prepared with regard to the special conditions in Jamaica.

Thus the present study is concerned with an economic analysis of the use of Jamaican red mud as a base material and Jamaican additives for purposes of the building industry specifically in that country. Therefore the results, conclusions and facts established in this paper should not be understood to refer to the alumina industry of any other country. In view of Jamaica's specific situation, particularly that it has a high-volume, advanced alumina industry, relatively low population and a rather limited building activity, the author had to confine himself to exploring the possibility of producing red-mud based good-quality materials for the Jamaican construction industry at a reasonable profit, and a study of how to utilize the total amount of red mud available is therefore beyond the scope of this paper.

2.2 Project History

After the respective subcontract entered into force, team leader Mr. F. Puskás and member of the expert team Mr. A. Geszti received their briefing on the project from Dr. E. Balázs, Head of UNIDO's Metallurgical Section.

A field trip aimed at familiarization with the local conditions and selection of potential additives took place from 28 February through 6 March and involved team leader Mr. F. Puskás and team members Dr. G. Sigmond and Mr. A. Geszti.

In Jamaica Mr. Puskás visited alumina plants and deposits of potential additives chosen on the basis of the literature and geological maps obtained from Mr. Wright J. A., Director and Mr. Mc Leod geologist of the GRC's library. He gathered samples at all locations. Among others, he visited the Kirkvine and Ewarton red mud disposal aeras, the Hodges quartz mine and the granodioryte deposits near Kingston. At all locations samples were collected.

In Budapest Mr Puskás tested about 5 kg of the samples in short laboratory tests with different components to find out, which materials he would like to be included in the one-ton sample to be sent from Jamaica to Europe for pilot scale testing. After determining the best two composition in his own laboratory he made glaze tests and high speed firing probes on 25 pieces of 50x50x5 mm crude pressed tiles of each of the two materials in the laboratory of Ferro Holland in Rotterdam. It was then established that Jamaican red mud and additives of a high SiO_2 content yield mixtures, which are suitable for the production of floor and wall tiles of the required quality by high speed firing, despite their unusually high Fe_2O_3 content. There was too little time in Jamaica to test the additives by making compounds of differing compositions and by firing, and the author only surveyed a few additive deposits on the spot. Thus in choosing the best of all the materials at his disposal he had only his scanty observations to rely on. The fact that each red mud sample he took back had a different $CaCO_3$ content made laboratory tests very difficult.

Following evaluation of the laboratory tests the author requested the Jamaican Bauxite Institute to send the following materials to Europe:

500 kg Kirkvine dried red mud /to be taken at the far end of the pond/
250 kg Hodges clay /Black River/
100 kg Hodges quartzsand /Black River/
100 kg Andrew clay /Above Rocks/
80 kg granodioryte grit /Blue Mountain/

The author's laboratory tests to produce bricks and roof tiles by traditional wet technology vacuum extrusion were unsuccessful. In spite of this he requested the Jamaican party to include additives for this purpose in their consignment for further laboratory tests. At our request and following Mr. Puskás's instructions, Händle Maschinenbau Mühlacker, West-Germany, the outstanding specialists in brick and roof tile production, performed the tests between la[illegible]ember and mid-December, 1982.

Using material received from Jamaica the author made further laboratory tests to establish the technical feasibility of making heavy ceramics products by methods other than vacuum extrusion.

Subsequent laboratory tests and the pilot plant demonstration of the dry pressing technology were performed at the Kochel am See facility of Messrs. Dorst Maschinen und Anlagenbau, something that was special importance since this firm had carried out a series of positive experiments in large laboratories and on an industrial scale with Hungarian red mud and additives. Also, one of Europe's most advanced pilot plants and test laboratories were built at Messrs. Dorst in the summer of 1982, and the Jamaican red mud project was the first complete job that needed all their equipment to perform. The production demonstration session, scheduled for May 1982, took place only late September due to logistic reasons. Very much indeed was at stake, since the size of the pilot equipment and the small amount of material components available allowed for no repetition and even the composition of the mixture had to be modified on the basis of the laboratory tests.

In accordance with the original project document two Jamaican observers arrived in Europe for the laboratory and pilot-scale testing: Mr. L. Nugent and Mr. E. Spence /Jamaica Bauxite Institute/. The production of various tiles from Jamaican red mud and additives was successfully demonstrated at the Dorst plant in the last days of September, 1982. Subsequent reports and economic calculations have been prepared, which are presented in further parts of this Report.

Chapter Three

Technical Report

3.0 Introduction

Jamaican red mud contains varying amounts of lime grains. It was the author's personal observation that in the area of the entry points of mud ponds the calcium carbonate contents of dried red mud samples is as high as 80-90 p.c, and it decreases across the pond due to sedimentation. Samples taken at storage areas farthest from the entry points contained practically no $CaCO_3$ grains. The material used in the various tests had about 15 % $CaCO_3$.

This means in practical terms that the red mud taken from mud ponds cannot be taken into consideration as a basic material for heavy ceramics products, if products of standard quality with reasonable life are to be produced. The reason for this is that during drying, the water-glass that develops in red mud in the technological process in alumina production and remains with it thereafter, sets as soon as it enters into reaction with the CO_2 content of the air, and it becomes impossible to turn the compound into a smooth slurry purely by steeping it in water, i.e. without exerting any mechanical influence on it. If, on the other hand, mechanical force is applied, the grains break up and become inseparable from mud. Even under laboratory conditions lime grains could only be removed from dried red mud with mild acid solutions. There is no difficulty, however, in mechanically removing from the mud coming from the plant lime grains larger than the size permitted by the type of product to be made and by the method of material preparation to be used. In the case of tile making by dry pressing, where materials are to be finely ground and lime grain sizes will be reduced sufficiently to render them harmless the problem comes from the fact, that calcium carbonate content effects klinkerization temperature range and holding time.

There are three alumina plants in Jamaica that currently turn out red mud. The author received analysis data for all three and reproduces these in Table 3.1. Most significantly Jamaican red mud contains a high amount of ironoxide. When developing the various formulas the author used Kirkvine red mud and other materials he received samples of. Before final formulas can be established however the changes in the analysis have to be measured that the removal of lime grains would bring about. As far as the materials suitable as additives are concerned, Table 3.2 lists the typical analysis data for the major clay deposits on the island.

One important aspect of the development of suitable formulas is the need for a suitable melting agent. The function of the melting agent is to expand the range in which firing can be carried out. There seem to be such materials available in Jamaica as their existance is mentioned by Mr. D.A.Holdridge, but at the time of our visit to Jamaica this information was not yet available, and the respective selection now appears less than optimal. In case there is commercial interest in a red mud ceramics project in Jamaica, final formulas will have to be developped for the products envisaged. There is no doubt in the authors' mind that, the quality of such products and the ease of their production can be further increased by refining the formulas used during the laboratory and production tests described in this report.

3.1 Heavy ceramics products /bricks, blocks, etc./

As it is in the production of structural and partitioning elements for the building industry that the largest quantities of raw material are consumed, our first objective was to see, whether any of the forming methods traditionally used by the ceramics industry for making such products /vacuum extrusion, casting into moulds, dry pressing/ could be applied to red mud based compounds, as well. Each forming method places distinct requirements on the compound to be used. The properties of red mud and the availability of suitable additives was of key concern.

The author further established a suitable method and the parameters of firing the products, and some promising results were reached in preparing compounds that do not require firing at all. These use cement and gypsum as binders, and should be further explored, before a final statement about their applicability can be made.

Laboratory test on brick and block making to be described later in more detail gave the following indications:

- Forming by vacuum extrusion has limited applicability as the plasticity of the red mud based compounds is low. The author believes however that by further effort it should be possible to develop a formula for products such as full bricks and blocks with few cavities using materials that are described in the geological literature of Jamaica, but to which he had not had access.
- Jamaican red mud lends itself sufficiently well to processing by dry pressing so that bricks and roofing tiles of reasonable quality can be made from compounds containing some 50 % red mud rendered free of lime agglomerates and of local materials that were made available to the author.
- For large building blocks the author managed to develop a formula based on 80 % lime-free red mud, on which the forming method used when making concrete blocks can be applied with good results.

The individual tests and their results are described below:

3.1.1 Laboratory tests on the production of bricks and roofing tiles by vacuum extrusion were carried out between 20 and 25 September, 1982 in the laboratories of Messrs. Händle

Mühlacker, Germany. For the tests four different body compositions were used according to formulas the author provided. Due to insufficient binding in the wet body the pressing results were relatively poor. The firing tests were carried out between 1 000 and 1 200 C^{o} and proper strength was achieved by sintering at a temperature between 1 100 and 1 200 C^{o}. The sintering effect at this temperature was not sufficient, however, to make good roofing tiles as these were not sufficiently waterproof.

3.1.2 A further test in the laboratory of the author in Budapest was intended to reveal whether a red mud compound free of $CaCO_3$ agglomerates could be rendered usable for dry pressing on a rotary hydromechanic or hydraulic brick making machine. Owing to the extremely high Fe_2O_3 content of Jamaican red mud its proportion in the compound could not be raised above 60 p.c. in a sharp contrast to the 75-80 p.c. of red mud contained in the cast product described below. Thorough and even firing of highly air-permeable bodies could be ensured by pressing large holes, cavities or a lot of small-diameter openings into the bodies and feeding extra amounts of air into the fire. It is possible however that in an extremely long firing cycle or in single-layer high-speed firing also solid bodies will be fireable.

The author has also made experiments related to the production of roof tiles by dry pressing. The two main points of interest were to make thin tiles of the required strength and to find a formula for the red mud compound that was waterproof. It was concluded that the same compound and preparations were suitable as for producing glazed ceramic floor and wall tiles. For strength red-mud based fired products outperform traditional fired clay tiles by a factor of 4. Traditional roof tiles being 12 mm thick on average, it is evident that even if dry pressed tiles are reduced in thickness to one half of traditional fired clay tiles, they will still compare favourably with the latter in terms of strength. Accordingly, the breadth and length of roof tiles will be primarily limited by pressing green strength and ease of handling. On the basis of trials with small laboratory samples it seemed probable that it would be possible to press 200x300 tiles both 15 mm and 5 mm thick, and that no handling problems are to be expected on subsequent production equipment. This was then confirmed by production demonstration at Messrs. Dorst, Germany, described in greater detail in section 3.2. Respective samples were presented to the visiting Jamaican officers.

3.1.3 Casting into an open mould combined with vibration for better filling is a standard method in making concrete building blocks. For the compound the author had to use red mud containing lime grains as he would have had destroyed the original grain structure of red mud in trying to remove them. He mixed this material with materials he received from Jamaica to prepare a compound that contained 80 % red mud /dry weight/ and was found to be suitable for casting into an open mould. It was established that the red mud block dries well in the open air and can be easily fired in kilns fuelled by wood or coal, as long as the pieces get sufficient amount of air during firing. A few pieces of 10" by 4" by 4" blocks were made in the laboratory, one of which was handed over to officers of the JBI in March 1983.

3.2 <u>Fine ceramics products</u> /glazed floor and wall tiles/

In the production of glazed tiles using a large proportion of red mud delicate technical problems have to be solved. Some of these problems are only apparent if the production is continuous and large uantities are produced. The technology and the formula for a semi-industrial scale production demonstration were elaborated using the results of the initial lab test in Kingston, Budapest and Rotterdam. The demonstration conducted by the author at the Dorst pilot plant with kind assistance from the following experts: Mr. Roschlau, head of Dorst test facility, Mr. Sladek, head of the technical laboratory, Riedhammer Co., Mr. Th. C. Pluym, senior staff member for ceramic glazes, Ferro Co., fully confirmed the validity of parameters used. During the production trial a few dozen square meters of glazed floor tiles, the same amount of glazed wall tiles and a few dozen pieces roofing tiles were produced in good quality. Samples of all products were given to the visiting Jamaican officials as well as were presented to the JBI in March, 1983.

In the formula for the glazed tiles that was also used to make roofing tiles Mr. Puskás used about 50 % Kirkvine red mud and selected additives from the materials we received from Jamaica. The following table shows the difference in the analysis of the red mud and the finished product.

	Kirkvine red mud	glazed ceramic tiles
SiO_2	3.04 %	48.64 %
Al_2O_3	13.20 %	11.29 %
Fe_2O_3	49.40 %	28.20 %
Na_2O-K_2O	4.0 %	2.10 %
CaO	9.4 %	6.0 %
TiO	7.3 %	4.40 %
P_2O_5	1.0 %	0.55 %
firing loss	12.5 %	-
Total	99.84 %	101.18 %

The production demonstration included the following technological steps:

1. Preparation of the material
2. Drying by atomization /granulation/
3. Pressing
4. Glazing
5. Firing

1. Preparation of the material
   The compound

We made a compound of 500 kg dry matter, and portioned it out into a Dorst MM 160/170 type wet drum mill with the help of a precision electronic balance.

	%	% H_2O	dry kg	H_2O kg	wet kg
red mud	50	6.5	250	17.4	267.4
silicate	50	6.24	250	18.2	257.7
water	-	-	-	-	298.3

The following values have been established for the milling operation:

Solids in the mixture: 60 % = 500 kg
Water content: 40 % = 333.4 litres
Electrolyte: Giesfix C 30 = 0.25 %
Grinding time: 4.5 hours

2. Drying by atomization /granulation/

We stored the body in a sludge mixer type Dorst UpM 30, keeping it in constant motion until it was granulated the following day. We then forwarded the mud suspended in the sludge mixer with a pulsating pump into an atomizer type Dorst 400 which evaporates 400 kg of water an hour. We used nozzle 2 mm in diameter for granulation. It took the atomizer 2 hours to granulate the total quantity. The air entering the atomizer was at 280 C^{o}, and its temperature dropped to 90 C^{o} when leaving it.

We used liquid gas as a heating medium. During granulation the atomizer was provided with automatic dust recovery i.e. particles of micron and submicron sizes could not leave with the outlet air, while with the help of a dust separator cyclone they were recirculated into the atomizer where they played an active part as seeds of agglomeration in the process of granulation.

Grain size and distribution figures are contained in Table 3.2.

As revealed in the Report almost 75 p.c. of granules fall in the 200-400 micron range. Moisture content was between 3 and 7 p.c. measured on leaving the atomizer, and stabilized at an average of 6 p.c.

3. Pressing

After allowing the granulated material to reach average moisture content in 24 hours, we used automatic control hydraulic presses types Dorst HPP 500/5 and HPP 700 for pressing tiles of the following sizes:

a/ HPP 500/5: 150x150x7 mm /5-cavity die/
filling depth: 10 mm

b/ HPP 700: 200x300x5, 10 and 15 mm /3 cavity die/
filling depth: 10, 20 and 30 mm

c/ Dorst laboratory press: 200x100x5, 10 and 15 mm /single cavity die/

Pressed tiles 150x150 mm and 200x100 mm served to demonstrate wall tiles, pieces 200x300x10 and 15 mm in dimensions represented floor tiles, while tiles 200x300x5 mm were used to demonstrate roof tiles.

Examining the green strength values of pressed tiles it can be stated that they correspond to the lowest figures obtained for traditional tiles. Green strength will certainly improve with an increase in grinding time, a modification in technology necessitated by other factors as well. After firing, however, red mud based tiles are on a par with traditional ones in strength.

4. Glazing

On the basis of the results of the trial firings with the unglazed tiles in the Riedhammer carriage kiln, Mr. Pluym has prepared the following two glazes to be used on the pilot scale glaze line:

A.1 = L.199 + L.203
A.2 = L.200 + L.203

We prepared glazes L.199, L.200 and L.203 out of the base dry milled materials, 50 kilo each, with a high speed mixer and with the addition of 35 % of water.

Litreweight of the glaze:

L.199 - 1 435 litre
L.200 - 1 425 litre
L.203 - 1 550 litre

Fineness of the glazes: 1 - 3 % 250 mesh

Quantity of tiles produced: 30 pieces 150 x 150 x 5 mm, A.1
and 30 pieces, A.2
20 pieces 200x 300 x 10 mm, A.1
and 20 pieces, A.2

Total dry weights per square metre:

Underlayer	200 grs.
Top layer	650 grs.
Production loss	50 grs.
Total	900 grs.

Mr. Pluym confirmed in his report sent to the author that he has not found any problems during glazing the tiles. He believes that the results with the glazed tiles are satisfactory but can still be improved if ground glazes are used, and the heat expansion value of the glaze used can be adjusted more accurately to fit that of the body.

5. Firing

With Mr. Sladek the author carried out the firing demonstration. The tiles were loaded onto the nailed grating of the firing carriage with the help of cordierite support plates.

We fired glazed and unglazed floor tiles of 200x100x8-15 mm and 300x200 mm in a cycle of 75-90 minutes and at a temperature of 1 180 - 1 190 C^{o}.

The firing curve could be set relatively easily, as no extra cooling time was required, since the porous low plasticity composition renders a rapid gasification of the organic particles /300-500 C°/ and the separation of carbon /700-800 C°/ possible.

Full scale trials were performed with all carriages loaded in the kiln.

In the case of unglazed tiles, dimensional stability and smoothness were achieved for long intervals. In the case of the glazed tiles, they were somewhat convex because of a slight difference in the heat expansion values of the glaze and substrate.

The subsequent examinations in the laboratory of Messrs. Riedhammer, Nuremberg showed the following: heat expansion value of $8.04.10^{-6}.K^{-1}$ /20-800 C°/ and a 25 p.c. free quartz content in the fired tiles.

In summary it could be shown in the production demonstration that it would be possible to produce glazed tiles and roofing tiles using some 50 % Jamaican red mud in good quality.

Table 3.1

Main oxide components of red muds that can be taken into consideration as a raw material for the ceramics industry in three alumina plants currently in operation:

	Kirkvine	Main	Ewarton
Al_2O_3	13.2 %	16.88 %	17.7 %
Fe_2O_3	49.4 %	41.62 %	47.3 %
TiO_2	7.3 %	5.56 %	6.4 %
SiO_2	3.04 %	5.72 %	4.13 %
P_2O_5	1.0 %	1.59 %	0.97 %
firing loss	12.5 %	10.48 %	13.0 %
CaO	8.5-10.1 %	8.97 %	7.1 %
Na_2O	2.0 %	4.07 %	3.5 %

Main oxide components of major Jamaican clay deposits that can be taken into consideration as additives to red mud in the ceramics industry:

Deposit	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	$CaCO_3$	$MgCO_3$	TiO_2
Frenchman	67.99	18.63	0.86	1.28	0.14	0.8	1.32	1.11
Liguanea	59.49	18.59	6.73	3.53	3.62	1.14	0.41	0.98
Hodges	76.24	12.24	1.25	0.08	0.24	0.70	0.67	1.12
Thatchwalk	50.52	21.44	7.95	0.52	1.54	1.30	0.90	1.02
Tulloch	59.77	17.48	6.41	4.81	4.57	2.11	2.76	0.96
Knollis	55.38	19.08	7.87	3.32	2.21	1.67	3.36	0.96
Sydenham	50.33	15.43	8.07	3.50	2.99	4.42	4.40	1.00
Ys Valley	43.3	26.9	9.6	0.1	0.4	2.50	0.7	1.4
Raheen Nassau	51.8	20.5	7.1	0.5	0.7	0.1	1.9	1.1
Oxford Nassau	48.7	24.7	7.3	0.1	0.2	0.7	1.4	1.2
Hampden	38.9	26.7	12.3	0.1	0.8	1.5	2.2	1.4
Frome	51.3	13.0	9.7	0.1	0.3	6.2	2.0	1.4

Table 3.2

Technical parameters of the semi-industrial scale production demonstration

Solids	kg.%	500-60
Water	kg.%	40
Giesfix C 30		0.25 %
Specific weight	g/l	1 620
Viscosity	cP	450
Screen mash		31 mm
Nozzle - vertically above		SpT - 100/6 000
Quantity	piece	1
Bore	mm ∅	2.0
Screw mm		Drall 4
Hot air temperature	C°	280/220
Outlet temperature	C°	90/80
Tower	mm WS	30
Main fan	mm WS	165
Pump	Kp/cm²	18
Residual moisture	%	3/7
Bulk weight	g/l	1 080
> 500	%	0.3
500-400	%	3.1
400-315	%	20.7
315-250	%	31.3
250-200	%	20.6
200-160	%	8.2
160-100	%	6.5
100- 50	%	0.7
< 50 micron	%	-

Chapter Four

Market and plant capacities

4.0 Introduction

Some 6 000 new homes are being built in Jamaica currently, with an average floor surface area of 54 sqm. Mr. Goldson of Goldson, Barrett, Johnson, chartered accountants, author of a study prepared for the Caribbean Development Bank believes 20,000 new dwellings would be needed in Jamaica each year. Any narrowing of this gap will be conditional upon a number of factors, the assessment of which would go beyond the scope of this study. In our further calculations an annual figure of 10,000 new homes will be taken as a basis.

In about fifty p.c. of the market glazed products are not expected to be able to compete with the low cost alternatives in floor and wall finishes as concrete and oil paint.

To build an average Jamaican home about 1 500 blocks will be needed for the outside walls and for one load-carrying inner wall, and the equivalent of some 2 000 standard /220x120x55 mm/ bricks for the inner partitions. It takes about 4 000 facing bricks to fully cover the outside surface of an average detached Jamaican house.

Shipping tiles from Kingston to New York in 20-foot containers currently costs $ 0.80 to $ 1.00 per sqm tile.

Data for the market survey was collected from statistical publications for the years 1979, 1980 and 1981, from interviews with Mr. Goldson, accountant, Mr. Gabay, building contractor, Mr. Leod, researcher and others.

4.1 An initial market assessment

4.1.1 Glazed Wall Tile

Domestic

Annual sales slumped from 11 million pcs /approx. 125 thousand sqm/ in 1975, to 1 million pcs in 1978, but can be reasonably expected to swing back to around 12 million pcs /135 thousand sqm/ as from 1982, and increase by 10 to 15 p.c. annually. Dealers typically charge up to J$ 40/sqm for the regular white 6" by 6" wall tile which costs about US $ 12 /c.i.f./ to import and carries substantial /up to 65 p.c./ customs duty. The market segment for higher esthetic value products /screen printed tiles, patterned tiles, hand painted tiles/ is estimated to be about 20 thousand sqm.

Since the total market is now served by imports, it can be reasonably anticipated that a local producer would meet no difficulty in taking over the supply of the bulk of the market, and that it would be possible for him to initially sell some 100 thousand sqm wall tiles with low to medium cost glazes at J$ 25/sqm.

Exports

We were told that the Caricom area currently has no glazed wall tile production, although there are glazing facilities in Trinidad. Imports of wall tiles of the MDC-s /Barbados, Trinidad and Tobago, Guyana/ have reached some 150 thousand sqm in 1975, those of LDC-s 35 thousand sqm in 1978. It should be possible for a Jamaican producer to capture 25 p. c. of the import market, with a similar product to that sold domestically, at an ex-factory price of about J$ 20.

A few meetings early this year in New Orleans suggested that the US market is open for the Jamaican tile exporter; with little or no import duty to be paid, depending on a piece of new legislation, awaiting congressional approval at the time of writing this report. There is plenty of room for a medium-quality product. To establish himself, the Jamaican producer's initial ex-works price may have to be as low as US $ 5, but can be increased subsequently.

4.1.2 Floor tile

Domestic

There are Terazzo and "Vibro" tiles produced in Jamaica. Imports are marginal /US $ 10,000 in 1978/. The whole market is over half a million sqm annually, half of which is concrete, some 10 per cent is carpet. Vinyl is imported. We weretold that some amounts of glazed floor tiles are also produced but were unable to get details. Terazzo sells at about 15 J$/sqm ex-works, Vibro makes products in sizes 7.5"by 7.5"and 10"by 10". Price per sqm is J$ 12 for the plain product and J$ 14 for the embossed one.

The unglazed RM-tile /quarry/ compares favourably with Terazzo and Vibro by virtue of its extreme strength and superior appearance. It seems reasonable to expect a 20 p.c. market penetration in the housing floor finishes market at J$ 18/sqm.

As for the glazed product, a large section of residential market might find it too expensive at prices over J$ 30/sqm /depending on the glazes used/ but it should be possible to sell 50 thousand sqm a year to the more affluent home builder, and for use in tourist facilities and commercial buildings.

Exports

Unglazed klinker tiles /quarry/ sell in large amounts in the South of the United States. One New Orleans dealer buys them at $ 1.50/sqft. /$ 16.50/sqm/ in the 6" by 6" format. This dealer also does business in rubble /broken quarry/, pays $ 5.50 for a sqm, and sells over 25 thousand sqm annually at about $ 8/sqm. Initially, US sales of a few ten thousand sqm-s at prices above US $ 6/sqm and Caricom exports of some 50,000 sqm at J$ 15/sqm are reasonable to expect.

The glazed floor tile has a significant export potential as it can be made to match in quality anything the market now has to offer. It will no doubt take some time before tiles made by a Jamaican producer can compete with the Italian and German tiles now selling at US $ 40 and over as this product is also a very delicate one to make. One might want to sell this tile in the North of the US, where its high strength and frost-proof feature could prove to be important sales arguments. The Caricom market may find the product expensive at J$ 25, and only a limited amount should be envisaged.

4.1.3 Roofing material /'ceramic shingle'/

Domestic

The roofing material market in Jamaica is over 1 million sqm in a year, /new homes, refurbishings, tourist trade installation, commercial buildings/. Corrugated aluminium sheets have the single biggest market share /some 60 p.c. according to one source/. This product is imported and sells at about J$ 16.50/sqm /the installed cost, excluding the cost of the substructure /battens/ is roughly J$ 27.50/.

Another popular product, Decramastic /a steel sheet with heat insulating coating/ sells at J$ 33/sqm, and costs J$ 44 to 55/sqm when installed. Shingles have a tradition but only a minor market share. Price: J$ 55/sqm. Clay roofing tiles sell at J$ 3.25/a piece /local product/ or more /imported/. Various discussions in Jamaica indicated that a ceramic shingle stands to gain a significant market share. Light weight, non-corrosiveness, high esthetic value and the fact that it is basically a domestic product, were named by the persons interviewed as advantages over the products presently available in the market. Higher manual labor requirement as compared to corrugated aluminium and Decramastic were not seen as serious drawbacks and it was felt that although the initial lack of persons skilled in its installation might slow down its market penetration, the product has a potential to take over some 50 p.c. of the market at a competitive price. Since these products are laid with 75 to 100 p.c. overlapping, 29 to 33 pieces of the 8" by 10" format make one sqm roof area. To sell really large quantities, the price may have to be as low as J$ 0.50/piece.

An engobed product with a more expensive image could sell at J$ 1/piece and compete with Decramastic.

Exports

We understand that the roofing market in the Caribbean area is basically similar to that in Jamaica, although it has not been possible for us to conduct concrete investigations. Because of the freight cost only the engobed product has been considered for export, though.

In the US and other advanced countries in the area, the thin roofing tile will have to compete with Eternit and slate. There is substantial interest in the product in Western Germany, where the chances of the red mud based roof tile to take away some market share from the other products is viewed optimistically by local investors.

4.1.4 Bricks & Blocks

Domestic

The degree of sophistication is rather low and choice is limited in the Jamaican market. Costs are relatively high also because the Building Code calls for steel bar reinforcement of structural walls.

Homes are basically built with cement-bonded blocks, and the annual brick production of the apparently only manufacturer, Clay Jamaica, is some half a million pieces a year. A housing programme of 10,000 homes a year would require approximately 15 million blocks for structural walls and the equivalent of some 20 million standard format bricks for partition wall use. It was not possible for us to get a clear understanding of the block production capacity and output in the short time we spent in the project area, because of contradicting statements. Presently there seems to be a block making capacity of 6 millions blocks. Cement is locally available from a 300,000 lg ton/year capacity cement plant, which would have to be extended, if it had to supply cement for a 10,000 homes-in-a-year housing programme.

Clays Jamaica sells its bricks at J$ 70 per 100 pieces, while blocks sell at J$ 80, 90 and 110 per hundred pieces, /Block length: 16", height 8", width: 4", 6" or 8"/.

There appears to be an uncovered demand of some 10 million blocks for structural wall and block flooring use in multi-storey buildings. Red mud based block would probably have to be offered at substantially the same price as are concrete blocks.

Red mud based bricks could be sold for use in partition walls, as facing products and for structural use by the upper market.

At ₵ 70/piece the market may not accomodate much more than sold now, and a more detailed study should confirm if about 6 million standard format bricks could be sold at J₵ 20 per 100 pieces, a price that is used in further calculations.

Exports

A more detailed study should reveal any opportunities for exports of red mud based blocks and bricks. This report takes the more conservative alternative and does not reckon with this possibility.

4.2 Plant capacities

The demand identified in the previous section could be fully satisfied by the combined outputs of a medium size tile plant /1,000,000 sqm/yr/ and brick/block plants having an aggregate capacity of the equivalent of some 130 million standard size /220x110x55 mm/ bricks or some 12 million blocks. For this total output the plants would consume about 450,000 tons of red mud /30 p.c. solids/.

More realistically, we feel that the initial plant capacities should be as low as economically feasible, and provisions should be made for possible further extensions. Consequently, it is proposed that a tile plant with a 250,000 sqm/yr initial capacity and a block/brick plant with an annual output of about 10 million standard units of bricks and 6 million blocks be established. Such an approach would hopefully reduce the risk involved to a tolerable level and attract enough capital for the plants to be built. An estimate of sales revenues for the plants proposed above is given in Table 4.1 and 4.2.

Table 4.1 Estimate of sales revenues, tile plant /at full capacity/

Product	Unit price /per sqm/ local /J$/	Unit price Caricom /J$/	Unit price other export US$	Quantities to be sold /1000 sqm/ local	Quantities Caricom	Quantities other export	Quantities total	Sales revenues 1000 J$	Sales revenues free Fx 1000 US$	Sales revenues total /1000 J$/
1. Glazed wall tile, 7 mm thick, various glazes	25	20	5	100	50	50	200	2500	250	3945
2. Glazed floor tile, 10 mm thick, various glazes	30	25	12	50	25	50	125	2250	600	3195
3. Quarry tile, 15 mm thick	18	15	6	100	50	50	200	2700	300	3085
4. Roofing tile, 5 mm thick,	8.50	-	-	325	-	-	325	2763	-	2763
same with engobe	17	15		100	50	-	150	2450		2450
Total	-	-	-	-	-	-	1000	12663	1150	14710

Note: The sales revenue of a 250.000 sqm/year capacity plant can be estimated at around J$ 5 million

Table 4.2[redacted] Estimate of sales revenues, [redacted]ck/block plant

/at full capacity/

Product	Unit price	Quantities to be sold	Sales revenue J$ 1000
1. Common brick 220x110x55 mm	J$ 20/100 pcs	5,750 000 pcs	1150
2. Facing brick 220x110x27,5 mm	J$ 12/100 pcs	2 million pcs	240
3. Terazzo tile 200x200x27,5 mm	J$ 50/100 pcs	2 million pcs /80.000 sqm/	1000
4. Building block 16"x8"x6"	J$ 100/100 pcs	6 million pcs	6000
Total	-	-	8390

Chapter Five

Project Engineering

A conceptual elaboration

5.1 Introduction

In this chapter details are given about the plants suggested in Section 4.2 of Chapter Four. As stressed at various places in this report, it is absolutely necessary for any utilization of Jamaican red mud to remove all large lime grains. It remains to be investigated if technology in the alumina plant can be modified so that no lime grains are introduced into the red mud to be used for ceramics purposes. This report offers an alternative solution to this problem, i.e. lime grains are removed as part of the operations at the ceramics plant.

When selecting the type of equipment to be used in the technology of either plant, an effort was made to seek a compromise among several considerations. To illustrate this, we should like to mention a few of them: On the one hand, product quality is best assured by automation and advanced technology, on the other hand, it appears to be one of the priorities of the Jamaican Government to create new jobs. Also, sophisticated production equipment, as used by German and Italian tile manufacturers, requires substantial skill to operate and maintain and will only give satisfactory results if serviced with the appropriate spare parts, which might not always be easy to obtain in Jamaica. It is encouraging to know, however, that the ceramics industry can flourish on relatively little tradition, and that the country that is now probably the largest single tile exporter in the world had no tile industry only fifty years ago.

5.2 Lime grains removal

The pressure line leading from the alumina plant to the mud pond will have a tributary pipe with a vibration sieve of 0.25 mm fineness at its end to hold back lime grain in the mud. The red mud, now free of lime grains, goes from the vibrator to a mixer drum from where a pump lifts it into a spraying system at 10 metres high, which sprinkles it in a fine spray onto one of two concrete drying surfaces underneath, each of which will have a final area of 3 000 sqm, when completed, operated in turns. The spray nozzles are located so as to evenly cover the concrete surface with mud.

Red mud spraying will run at a capacity of 10 kg/hour/sqm for 8 hours in the hottest period of the day. With 240 tons of red mud sprayed every working day, the drying facility may receive a total of 1 440 tons in 6 days. Red mud will then cover the concrete surface 20 centimetres thick. In contact with warm air, red mud will lose most of its moisture content and the rest will keep evaporating until the next spraying cycle. Disposal of the dried mud begins on the 8th day and is carried on at 240 tons a day for 6 consecutive days. Drying may take place on a total 300 workdays in 50 weeks of the year at an annual capacity of 72,000 tons. The moisture content of dried red mud is at a maximum of 8 p.c. on the first day and 2 p.c. on the 6th day, the average being around 5 p.c. Averaging the moisture content takes place in the base material stores of ceramics factories.

5.3 Tile plant

- Storing

Red mud free of lime grains as well as the additives are kept in a covered concrete shelter, each in a quantity of about 800 tons, which feeds the plant for a whole month.

- Feeding

Red mud and the additives are fed into the wet ball mill with due consideration to their solids content. Red mud and additives should be in a proportion of 50:50. Water inflow is controlled with a water-meter, and is allowed up to 40 p.c. of moisture content. For an electrolyte /de-watering fluxing material/ we use 0.25 p.c. Giesfix C 30 or 0.2 p.c. tripolyphosphate.

- Grinding

Wet grinding takes place in ball mills of 3 000 kg effective capacity in 6-hour cycles.

- Homogenization

3 batches leaving the ball mill are fed into a 9 000 kg propeller mixer, where the sludge is allowed to stand for a minimum of 12 hours. Its litre weight is 1 600 - 1 700 g, its viscosity is 400-600 cP.

- Granulation

After leaving the mixer the sludge passes through a vibration sieve and is fed by a pump into an atomizer, where it is granulated by spraying and drying. The atomizer has a capacity of 3-5 tons/hour.

- Pressing

Having been allowed to stand, the granulated material goes into a hydraulic press with a capacity of 18 strokes minute and 215 sqm/hour if 5 dies, each 200x200 mm in nominal dimensions, are employed.

- Drying

The pressed tiles in dimensions of
200x200x5, 10 and 15 mm, and
200x300x5, 7.5, 10 and 15 mm
are kept for a few minutes in a compensor before going into the feeder of a vertical quick drier and then to the drier itself.

- Glazing

In order to increase the aesthetic and utility values of floor and wall tiles, they are coated with glazes of different colour, quality and purpose on an automatic glazing belt. Roof tiles are provided with a layer of engobe on the same device. The various kinds of glaze and engobe are prepared in a separate shop. Glaze requirement: 1 kg/sqm, engobe requirement: 0.2-0.3 kg/sqm.

- Storage

The glazed tiles are placed on racks by an automatic handling machine both before and after firing. The storage system enables continuous firing. When filled to capacity, the system stores material enough for 60 hours of firing.

- Firing

The glaze is fired and the tiles solidified in a roller kiln providing for single-layer rapid firing. The kiln runs in continuous operation except for periods of repair. Its firing capacity is 150 sqm/hour.

- Sorting

After going through the storing system, the fired tiles undergo sorting, a partly automated procedure, in which control of dimensions flatness and shape is automated, while aesthetic deficiencies and other defects are screened by skilled personnel. The product is classified into 4 qualities, namely I. export class, II. first class, III. second class, IV. third class. Export quality implies freedom of aesthetic blemishes and deformation and fullfilment of the upper limits of standards for physical properties. First-class tiles are free of aesthetic defects and deformation and the physical properties are at the lower limits of the standard. Second-class products have physical properties satisfying the standard, have perfect shape but are aesthetically inferior to those in higher classes. Third-class tiles are allowed to have cracks and chips, and floor tiles may have defects in shape as well. If a product does not fit into any of these classes it is regarded as rubble, but can be ground and returned to base material.

- Packaging

Sorted export quality and first-class tiles are packed into prefabricated card board boxes, 1 sqm/box; second and third-class products as well as roof tiles are bandaged into corrugated paper, 1 sqm/bandage, tied up with an instant fastener.

- Delivery

Boxed and bandaged products are placed on pallets, 40 sqm/pallet on average, tied up with plastic ribbons, and delivered to users or ports in container trucks.

5.4 Heavy ceramics products

- Storage

  The crude red mud, dried and free of lime grains is kept on concrete coated storage area in a quantity of 4 000 tons, which provides base material for one month of production. The 1 300 tons of additives are stored in a similar manner.

- Granulation

  Building blocks are produced from splintered red mud broken to the size of max. Ø 20 mm in a 20 ton/hour capacity jaw crusher and granulator.

- Storing

  Granulated red mud is sorted on a two-plane vibrator. The finer portion will be used to make bricks, the other for producing building blocks.

- Milling the additive

  For brick manufacture both red mud and the additive have to be milled into grains of less than 1 mm with the help of a desintegrator and a pair of smooth rolls.

  The additive for building blocks is ground in a wet drum mill. The sludge contains about 50 p.c. of water after milling.

- Feeding

  The components for producing bricks are weighed in vibrator feeders and layered on top of each other on a conveyor belt.

  In building block production the red mud and the additive are fed in by volumetric weighing.

- Homogenization - mixing

  In brick production the layers of base and additive materials are fed from the conveyor belt into a single axis mixer for homogenization.

  The materials and the wet-ground additive for building block production are homogenized in an Eirich type mixer.

- Granulation

  For the semi-wet pressing of bricks the compound is granulated in Koller-machines and, following conditioning and homogenization the granulated material is sent through a vibrator.

- Pressing

  Bricks are pressed on a mechanical or hydraulic brick moulding press.

  Blocks are shaped in moulds or by vibrator-mechanical or hydraulic presses.

- Drying

  After pressing the products are dried in a shelter with a roof in the open air.

- Firing

  Firing is carried out in a tunnel kiln equipped with cars, sleighs or firing cases.

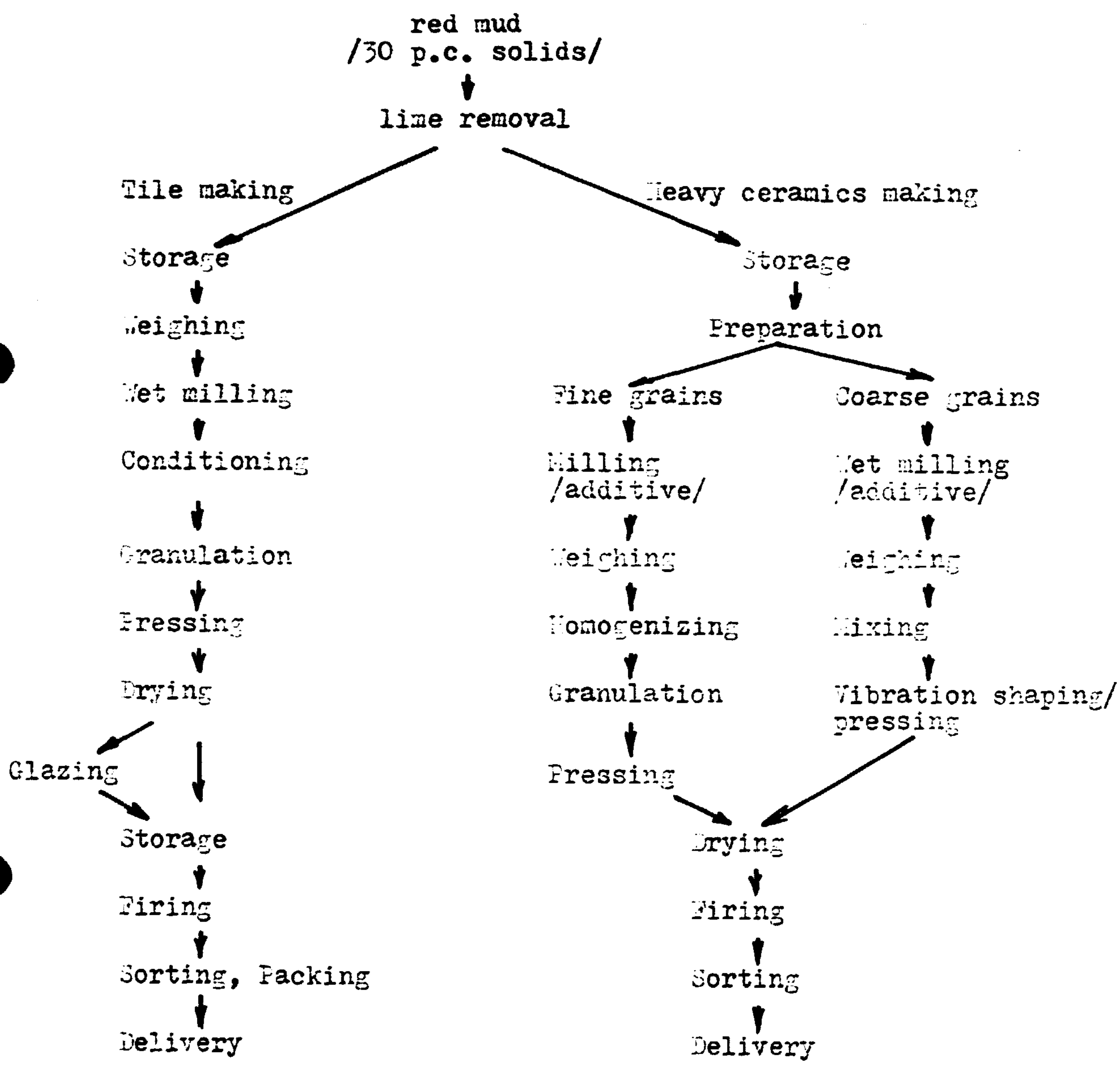
- Sorting

  The products are classified by skilled personnel: broken and deformed pieces are removed.

- Delivery

  In bulk or on pallets by lorry.

5.5 Technological scheme



5.6 Machinery and equipment, tile plant

Item	Equipment	Cost of equipment for initial 250 000 sqm annual capacity: Fx in 1000 $	local currency 1000 J$	total cost 1000 J$	Cost of equipment for additional 500 000 sqm annual capacity: Fx in 1000 $	local currency 1000 J$	total cost 1000 J$
1.	Body preparation + storage	450	100		600	50	
2.	Pressing	195	-		240	-	
3.	Drying	110	-		190	-	
4.	Glazing & storage	250	-		400	-	
5.	Firing	310	-		540	-	
6.	Sorting and packing	30	-		30	-	
7.	Materials handling, internal transport	-	50		-	50	
8.	Laboratories, workshops, glaze preparation	50	50		60	20	
9.	Seaworthy packing	25	-		30	-	
	Total, machinery and equipment, f.o.b.	1430	200	3931	2040	120	3750

5.7 Machinery and equipment, Brick/Block making plant

Item	Equipment	Fx in 1000 $	Local currency 1000 J$	Total currency 1000 J$
1.	Red mud preparation, storage	500	1110	
2.	Material preparation, bricks	250	50	
3.	Dry pressing, bricks	80		
4.	Material preparation, block making	350	100	
5.	Shaping, blocks	200		
6.	Drying		50	
7.	Firing	700	600	
8.	Laboratory and workshop equipment, tools	65	50	
	Total, machinery & equipment, f.o.b.	2145	1950	5770

Chapter Six

Financial and economic evaluation

In the following tables preliminary figures are presented in an effort to illustrate the extent of economic feasibility to be expected from the utilization of Jamaican red mud for building materials as described in other parts of this report in greater detail.

It will certainly be appreciated that a number of factors that have an influence on the final outcome, e.g. on the internal rate of return, had to be selected more or less arbitrarily. Nevertheless we made genuine attempts to arrive at realistic selections.

One such selection has been the type of fuel to be used and its price. It is proposed that for firing in the heavy ceramics plant and for drying in the tile plant local fuel /peat, charcoal, wood, or bagasse if available/ be used. The price of J£ 4 per million kJoule of local fuel used in the calculation is taken from a Government Report on the Energy Plan for Jamaica. The same source also indicates the absolute availability of these fuels. The final decision on the type of local fuel and the determination of its actual availability go beyond the scope of this report.

As tile firing requires higher-quality fuels /ashfree, low-sulphur, etc./, it has not been possible to propose a local alternative. Consequently, the report is based on the use of imported fuels. It is proposed that such a plant would nevertheless have a beneficial effect on the foreign exchange balance of Jamaica in the final analysis. With a view to this the cost of imported energy has been calculated without import duty or a similar government surcharge. Both plants require a good deal of electric power. Although it might be worthwile to investigate the possibility of using power generated at the alumina plant, the red mud of which is to be used, the current utility rate including government surcharge has been adopted for the calculations.

The cost of red mud has been chosen arbitrarily, as it was viewed premature at this stage to try to solicit a quotation from operators of the alumina plants. The costs of additives have been chosen to be in line with current Jamaican prices of similar mining products. Here again no quotations have been asked for, since a final selection of these materials will have to follow later, subject to technological, logistic and other considerations.

Plant equipment and machinery have been costed using budgeting estimates we received from various European manufacturers of heavy and fine ceramics equipment. Respective local cost components have been estimated, and will have to be verified against quotations from local contractors.

In establishing costs relating to land, site preparation, factory buildings, etc. indications received from Mr. Henderson Davis, JNDC for lease of industrial facilities were used. Wages and salaries were estimated on the basis of information received from JNIP.

In order to keep things managable depreciation is calculated at a flat 10 p.c. and no government subsidies have been used except for a tax holiday on corporate taxduring the initial nine years of both plants.

The economic and financial calculations have been prepared along the guidelines contained in the UNIDO Manual for industrial pre-feasibility studies. Plant sizes used in this calculations reflect the wish expressed by the Jamaican counterpart during review of the Draft Final Report that the smallest economically feasible unit be considered.

The rate of exchange used in this Report is J$ 1.78 to 1 US$.

In summary the authors think that they could prove both the technical as well as the economic viability of using local red mud in the production of tiles, blocks and bricks in Jamaica and are happy to offer their collaboration in any further work to implement the findings of this report.

Table 6.1 Total Investment Cost, Tile Plant

Item	Investment Category	Foreign currency /U$ 1000/ 1	Foreign currency /U$ 1000/ 2	Local currency /U$ 1000/ 1	Local currency /U$ 1000/ 2	Total cost /U$ 1000/ 1	Total cost /U$ 1000/ 2
1.	Utility connections, auxiliary and service facilities	-	-	300	200	300	200
2.	Plant machinery and equipment, FOB European Port	1430	2040	200	120	2750	3750
3.	Freight, insurance, local services	50	60	100	150	200	100
4.	Office and plant furnishing	-	-	200	100	200	100
5.	Sub Total, Initial Fixed Investment Costs	1400	2100	800	570	3450	4300
6.	Investment study	-	-	100	-	100	-
7.	Engineering, detail planning	200	-	-	-	150	-
8.	Assembly, start up and test run of equipment and plant	200	100	250	400	600	580
9.	Down Payment, Licence, Technical Assistance	175	350	-	-	300	620
10.	Sub Total, Pre-production capital expenditures	575	450	350	400	1150	1200
11.	Working capital	-	-	500	1000	1500	1000
12.	Contigency	200	150	220	230	580	500
13.	Total	2255	2700	2370	2200	5680	7000

Note 1: Costs for 250.000 sqm/yr /1/ and additional 500.000 sqm/yr /2/ capacity

2: A licence for the technology can be obtained under agreement with the owner, Messrs. Inter Ceramic Corp. Inc: Zug, Switzerland.

Table [redacted] Total investment cost, bri[redacted] plant

Item	Investment category	Fx US $ thousand	Local currency 1000 J$	Total thousand J$
1.	Utilities, auxiliary and service fac.	-	500	500
2.	Plant machinery & equipment f.o.b. European port	2145	1950	5770
3.	Freight, insurance, local service	-	400	400
4.	Office and plant furnishing	-	150	150
	Sub total, initial fixed inv. costs	2145	2500	6820
5.	Investment study		150	150
6.	Engineering, detail planning	175	-	312
7.	Assembly, start up and test run of equipment and plant	100	200	378
8.	Licence technical assistance; down payment	400	-	710
	Sub total, pre production capital expenditures	675	350	1550
9.	Working capital	-	1000	1000
10.	Contingency	150	230	500
	Total	2970	4580	9870

Table 6.3 Total production cost, tile plant

a/ For stage 1 = 500.000 sqm/yr and Stage 2 = = 1 million sqm/yr annual production

Item	Cost component	Fx /1000 US$/ stage 1	Fx /1000 US$/ stage 2	local currency /1000 J$/ stage 1	local currency /1000 J$/ stage 2	total cost /1000 J$/ stage 1	total cost /1000 J$/ stage 2
1.	Materials	225	451	180	361	581	1164
2.	Utilities & energy	413	827	482	964	1218	2436
3.	Other direct materials	75	150	110	220	243	487
4.	Wages and salaries	144	144	432	690	688	946
5.	Other items	379	740	761	1340	1440	2560
	Total	1236	2312	1965	3575	4170	7593

b/ For Stage 0 = 250.000 sqm/yr annual production

Item	Cost component	Fx /1000 US$/	local currency /1000 J$/	total cost /1000 J$/
1.	Materials	112	90	290
2.	Utilities & energy	220	240	610
3.	Other direct materials	40	55	125
4.	Wages and salaries	144	300	560
5.	Other items	250	430	880
	Total	766	1115	2465

Table 6.4 Production Cost Items, Tile Plant

VARIABLE COSTS

Item	Requirement[1]	Unit	Cost component	Unit cost	Cost in Fx /1000 US $/	Cost in local currency /1000 J$/	Total cost /1000 J$/	Variable cost per sqm /J$/
1.	8 500	t	Red mud, 95 % solids	J$ 5	-	42.5	42.5	0.5
2.	8 500	t	Minerals A and B[2] combined, 95 % average solids	J$ 30	-	255	255	0.25
	8 500	ton x 50 km	Freight[3]	J$ 7.5 ton x 50 km	-	63.75	63.75	0.10
3.	40	t	Electrolite	1 500 US $	60	-	107	0.10
4.	275	t	Engobe	150 US $	41	-	73	0.10
5.	200	t	Glaze, group 1 for 200 thousand sqm	750 US $	150	-	267	1.34
6.	100	t	Glaze, group 2 for 100 thousand sqm	2 000 US $	200	-	356	3.56
7.			Sub Total Materials		451	361.25	1164	2.49[4]

Note 1: Requirement for one million sqm/year production
2: Additives as per proprietary formula
3: For additives only
4: For tile with low cost glaze /item 5/

Table 6.5 Total Production Cost: heavy ceramics Plant

Item	Requirement	Unit	Cost Component	Unit Cost	Total Cost /J$ 1000/	Cost per 1000 Standard bricks /J$/	Cost per 100 blocks /J$/
1.	56.2	1000 tons	Red mud, 95 p.c. average solids	J$ 5/ton	281	6.67	3,75
2.	22	1000 tons	Additives, 95 p.c. average solids, combined	J$ 10	220	8.93	2,5
3.	22	1000 tons	Freight, 50 km	J$ 7.50 per ton x 50 km	165	6.7	1.9
4.	25	10^3 kg	Lubricant	J$ 3/kg	75	2	1
5.	-	-	Replacement parts	-	180	7.2	2
6. Sub Total Materials					921	31.5	11,15
7.	1	10^6 kWh	Electricity, energy charge	J$ 0,36/ kWh	360	7.2	5
	250	kW	demand charge	J$ 25.8/ kW max. demand	6.5	-	-
8.	78 330	mill kJoule	Fuel /Bagasse, Wood, Charcoal, Peat, Coal/	J$ 4			
	210 000		4200 kJ/kg product: brick 3500 kJ/kg product: block		313 840	27.4	14
9.	1 000	1000 gallons	Water	J$ 5.50	5.5	-	-
10. Sub Total Utilities and Energy					1525	34.6	29

Item	Requirement	Unit	Cost component	Unit cost	Cost in Fx /1000 US $/	Cost in local currency /1000 J$/	Total cost /1000 J$/	Variable cost per sqm /J$/
8.	2.5	10^6 kWh	Electricity, energy charge	J$ 0.36/ kWh	-	90	90	0.90
	950	kW	demand charge	J$ 25.8/kW max.demand	-	25	25	
9.	7 800	mill. kJoule	Fuel /Bagasse, Wood, charcoal, Peat or Steam/ for vertical dryer		-	31	31	
10.			Fuel /Fuel, Oil, Alcohol, Gas from Wood/	US$ 6				1.5
	51 000	mill. kJoule	for spray dryer		306	-	545	
	86 700		for roller kiln		521	-	927	
11.	1 500	thousand gallons	Water	J$ 5.50	-	8	8	0.0
12.	Sub Total Utilities and Energy				827	964	2 436	2.4
13.	40	10^3 kg	Lubricant Oil, etc.	J$ 3/kg		120	120	0.1
14.	-		Replacement Parts	-	150	-	-	0.3
15.	-	-	Packing material, etc.	-			100	0.1
16.	Sub Total, Other Direct Materials				150		220	0.5
17.	Total Variable Cost			-	1 428		1 545	5.4

NON-VARIABLE COSTS

Item	Requriement Stage 1	Stage 2	Unit	Cost Component	Unit cost	FX /1000 US$/ Stage 1	Stage 2	Local Currency /1000 J$/ Stage 1	Stage 2	Total Cost /1000 J$ Stage 1	Stage 2
18.	120	86	1000 hrs	Wages, for 52 weeks, 44 hours a week, with 20 % allowed for absences	J$ 3/hr	-	-	360	618	360	618
19.	48	-	months	Salaries, for a technical director, a plant manager, foremen	US$ 3 000	144	144	-	-	256	256
20.	72	-	months	Salaries for staff /secretary, driver, laboratory and office clerks/	J$ 1 000	-	-	72	72	72	72
21.	Sub Total, wages and salaries					144	144	432	690	688	946
22.	-	-	-	Overhead /administrative and selling/	-	50	100	300	600	389	778
23.	70 000	50 000	sqft	Lease of factory	J$ 5.30 per sqft	-	-	371	530	371	530
24.	300 000	-	sqft	Lease of land	J$ 0.20 per sqft	-	-	60	60	60	60
25.	-	-	-	Depreciation, machines and equipment at 10 %		204	390	30	50	400	750
26.	-	-	-	Licence fee 3 p.c. of sales revenue	-	125	250	-	-	220	440
27.	Sub Total Other Items				-	379	740	761	1 340	1 440	2 560
28.	Total Non-Variable Costs				-	523	884	1 193	2 030	2 123	3 506

Table 6.6 Calculation of th[illegible]nternal Rate of Return; Tile [illegible]ant /Values in J$ million/

Period	Stage 1: Construction	Stage 1: Start up		Stage 1: Full Capacity			Stage 2: Installation and start up	Stage 2: Full Capacity					Salvage value in last year	Total
Year	1	2	3	4	5	6	7	8	9	10	11	12		
Production Programme /%/[2]	0	25	40	50	50	50	75	100	100	100	100	100		
A. Cash inflow	0	3.7	5.9	7.35	7.35	7.35	11.0	14.7	14.7	14.7	14.7	14.7	7.0	
1. Sales revenue	0	3.7	5.9	7.35	7.35	7.35	11.0	14.7	14.7	14.7	14.7	14.7	7.0	
B. Cash outflow /1+2+3/	6.3	6.4	3.2	3.77	3.77	8.30	8.5	6.85	6.85	10.36	10.36	10.36		
1. Total investment outlay	6.3	6.4	0	0	0	4.58	2.5	0	0	0	0	0		
2. Operating costs, less depreciation	0	2.4	3.2	3.77	3.77	3.77	6.00	6.85	6.85	6.85	6.85	6.85		
3. Corporate tax at 45 p.c.	0	0	0	0	0	0	0	0	0	3.53	3.53	3.53		
C. Net cash flow /A-B/	-6.3	-2.7	2.7	3.58	3.58	-0.95	2.5	7.85	7.85	4.34	4.34	4.34		
D. Net cash flow discounted at internal rate of return /28 p.c./	-4.9	-1.64	1.25	1.27	0.98	-0.20	0.42	0.98	0.75	0.33	0.25	0.20	0.29	0

Note: 1. Tax holiday up to year 9
2. 100 % = 1,000,000 sqm

Item	Requirement	Unit	Cost Component	Unit cost	Total Cost /J$ 1000/	Cost per 1000 Standard bricks	Cost per 100 blocks /J$/
11.	275	1000 hrs	Wages, 120 workers	J$ 250	687.5	-	-
12.	120	months	Salaries, management and 6 staff	J$ 2 500	350	-	-
13. Sub Total, Wages and Salaries					1037.5	24	14
14.	-	-	Overhead /Selling and Administrative/		500		
15.	50	1000 sqft	Lease of Factory	J$ 5.30/ sqft	265	24	11
16.	500	1000 sqft	Lease of Land	J$ 0.2/ sqft	100		
17.	-	-	Depreciation/machines and equipment at 10 p.c.	-	577	26	6
18.	-	-	Licence fee, 3 p.c. of sales revenue	-	240	4.5	3
19. Sub Total Other Items				-	1682	54.5	20
20. Total Production Cost				-	5165	145	74.5

Table 6.7

Demonstration of the economic feasibility of a 250.000 sqm/yr capacity tile plant

	in J$ 1000
Sales revenue from Table 4.1	5.000
Operating costs from Table 6.3.b, less depreciation	- 2.200
Total operating profits	2.800

Initial capital outlay of J$ 5.7 mn is payed back from profits in two years.

Table 6.8 Calculation of Internal Rate of Return; Block/Brick Plant /Values in J$ million/

Period	Construction	Start up		Full Capacity									Salvage value in last year	Total
Year	1	2	3	4	5	6	7	8	9	10	11	12		
Production Programme	0	25	80	100	100	100	100	100	100	100	100	100		
A. Cash inflow	0	2.1	6.7	8.39	8.39	8.39	8.39	8.39	8.39	8.39	8.39	8.39	2.0	
1. Sales revenue	0	2.1	6.7	8.39	8.39	8.39	8.39	8.39	8.39	8.39	8.39	8.39	2.0	
B. Cash outflow /1+2+3/	8.0	4.0	4.3	4.6	4.6	4.6	4.6	4.6	4.6	6.3	6.3	6.3	-	
1. Total investment outlay	8.0	1.9	0	0	0	0	0	0	0	0	0	0	-	
2. Operating costs, less depreciation	0	2.1	4.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	-	
3. Corporate tax[1] at 45 p.c.	0	0	0	0	0	0	0	0	0	1.7	1.7	1.7	-	
C. Net cash flow /A-B/	-8.0	-1.9	2.4	3.79	3.79	3.79	3.79	3.79	3.79	2.01	2.01	2.01	2.0	
D. Net cash flow discounted at the internal rate of return /25 p.c./	-6.400	-1.216	1.229	1.554	1.24	0.993	0.796	0.637	0.508	0.223	0.180	0.144	0.11	0

Note: 1. Tax holiday up to year 9

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