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Brickmaking in Developing Countries

by John Parry

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Brickmaking in developing countries

A review prepared for the Overseas Division, Building Research Establishment, UK

by
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FOREWORD

The changes imparted to earth by heating in a kiln have been known from ancient times, and burnt brick has become one of the major construction materials in many parts of the world. It may often be the most appropriate building material where indigenous clay resources exist and where some form of fuel is available. In the last few years there has been renewed interest in the use of brick in some developing countries, especially in those where the use of alternatives would require the expenditure of foreign exchange.

As part of its programme of research into indigenous building materials, the Overseas Division of BRE initiated a research and development project aimed at improving brickmaking technology in developing countries. As an early part of this project, BRE sought to review the many different techniques in current use and to identify subjects for future research.

BRE approached Mr J P M Parry, a director of the London-based Intermediate Technology Development Group, and chairman of J P M Parry and Associates, to carry out this review under contract. After graduating from the University of Keele, Mr Parry worked overseas for several years, having control over rural development projects in a remote area of northern Borneo. More recently he has been a consultant to the ceramics and building materials industries. He has carried out feasibility studies and set up brick and tile making plants in many countries, ranging from highly mechanised facing brick factories in Europe to small hand-made brick and tile [illegible] in African villages.

As the review appeared to be of interest to a wider group of readers, it has now been produced in the form of this BRE publication. The information is based necessarily upon the knowledge, experience and views of the author and because of the world-wide nature of the study undertaken, it has not been possible for BRE to confirm every detail.

The report examines the range and economics of various technologies, and explains the causes of common production defects. A comprehensive review is made of brickmaking in nearly 40 different countries, methods in about 1/3rd of these being described in considerable detail. The review closes with recommendations for research to improve existing technologies. It is hoped that the publication will prove useful to research and development workers seeking to improve production methods, and will also serve as a reference for all those who may be involved in building and construction throughout the developing world.

R G Smith
Overseas Division
Building Research Establishment

CONVERSION FACTORS

1 mm	= 0.0394 in
1 m	= 1.09 yd
1 tonne	= 0.984 UK ton
1 N/mm²	= 145 lbf/in²
1 MJ/tonne	= 933 Btu/UK ton

CONTENTS

PART A: INTRODUCTION

Background and approach

Brickmaking in one form or another has existed in a majority of countries and there are considerable similarities in many of the methods employed. The main scope of this study includes some concentrated descriptions of production methods employed in twelve sample countries from areas of East, West, North and Southern Africa, East and West Asia, Latin America and the Caribbean, with briefer reference to particular features in several other countries outside this group. Detailed technical matters such as clay analysis or topographical features of individual locations are not encompassed in this study as these are not generally relevant to an overall review of this kind.

The approach used to help identify priorities for research and development has been first to assess working methods and conditions, tools and equipment, scale of operation and workplace layouts in brick plants in a variety of countries with comments on productivity, consumption of fuel and other resources related to output, and the limitations to quality of product derived from choice of technology. To relate these descriptions to research and development needs, a summary section has been prepared describing circumstances in the different countries in order to identify technical inadequacies which occur over a significant part of the field and which hold out promise of being improved by appropriate research and development effort.

Experience

The main source of information incorporated in this study is from previous survey and practical fieldwork undertaken by the author, often in the course of constructing or improving brick production facilities in the developing world. Most of the technical considerations surrounding traditional brickmaking industries have been found to have direct relevance and similarity to circumstances in heavily capital-intensive brickmaking in Europe and the United States, and experience has been drawn from both sectors in judging requirements for research and development.

Although primarily a deskwork exercise reprocessing illustrative and factual information already to hand, all of the views expressed in the commentary and the recommendations for future work are qualified by direct and recent practical experience in most of the countries described in the survey. While the study concentrates on the **indigenous** brickmaking technologies employed in developing countries, reference where appropriate is made to the occasional highly mechanised factory which has been installed in these countries. The source of information about these plants including how they operate is again mainly derived from direct experience and from published information.

Acknowledgements

The descriptions of brickmaking processes and some of the problems associated with them are mainly drawn from work in the field and acknowledgements are due therefore to the local counterpart organisations with whom the author collaborated and to the overseas aid and development bodies and private companies through whose auspices it was possible to visit the various countries:

UK Ministry of Overseas Development
Royal Netherlands Government, Overseas Aid Ministry.
Economic Commission for Africa, Addis Ababa, Ethiopia
United Nations Environment Programme, Nairobi, Kenya
The Commonwealth Secretariat, London
United States Agency for International Development
Government of Pakistan, Ministry of Economic Affairs
Government of Tanzania, Small Industries Development Organisation
Basotho Enterprises Development Corporation, Lesotho
Building and Road Research Institute, Ghana
Christian Aid/Sudan Council of Churches
Regional Development Corporation, Southern Sudan
Oxford Committee for Famine Relief

Ministry of Finance and Industrial Development, The Gambia
Ministry of Finance, Botswana
Messrs Phillips Petroleum Inc
P-E Consulting Group Ltd, UK
Berenschot Moret Bosboom, Netherlands
EPEB, Burundi
Desarrolo Juvenil-Comunitario, Honduras

The illustration of brickmaking in China on page 66 was taken from an Arts Council exhibition of Peasant Paintings from Shensi Province, China.

Grateful thanks are also due to individuals who contributed written or illustrative material or personal experience and views which helped in the preparation of this study, to members of ITDG's Building and Building Materials Panel: Nicholas Greenacre, Liverpool School of Tropical Medicine; Dipl Ing Jules Janssen, University of Eindhoven; Dr Robin Spence, University of Cambridge; and to other associates and correspondents of the Panel including Messrs Caspar de Groot, Peter Bekker, Ken Shemilt, Desmond Trigg and M D Simpson.

PART B. ECONOMICS OF CHOICE OF TECHNOLOGY

Range of brickmaking technologies available

A very wide choice of technology is available to anyone contemplating brick manufacture although the higher the capital intensity, the more restrictive the process is to the type of clays which can be handled. High technology brickmaking is also restrictive in the form the energy required can be used. The very high mechanised and automated plants rely on electric power and the higher grades of fossil fuels such as natural gas and propane while traditional plants may use scrub wood or even camel dung as their only source of process energy (other than human muscle-power).

Operating costs

At the highest level of mechanisation and automation which has been attained in the clay brick industry the input of labour is less than one man hour per thousand bricks, around one twentieth of a minute's work per brick produced. At the highest level of labour intensity in unmechanised brick plants, the labour content may be as high as 10 minutes work per brick — 167 manhours per thousand bricks. However, the relative cost of labour also varies over almost as great a range with some brickworks' labour in the United States earning as much as £5 an hour while in parts of Africa the hourly wage may be as low as 5 pence.

If we relate the highest labour rates to the most automated factory we arrive at a labour cost of £5.00 a thousand bricks (1 manhour x £5). On the other hand the most labour-intensive brick plants with the lowest unit labour rates result in a labour cost of 167 manhours x 5 pence a thousand bricks: £8.35, only slightly higher than the labour costs of the most automated plant and this £8.35 is their **only** significant cost and includes the work of gathering fuel. It is therefore possible for grossly labour-intensive brick factories in developing countries to put bricks on the market at between £10 and £25 a thousand. By contrast the automated factory has a whole range of other costs to contend with including fuel, power, spare parts, process additives and supplementary materials as well as the cost of providing the capital and depreciating the equipment. As a result by 1978, brick prices in the developed world were mostly in excess of £50 a thousand, more than double the price of the developing countries' Bricks — that is those made in the very labour-intensive production units.

However, in spite of the fact that the relative costs of labour and capital mitigate against heavy mechanisation, a considerable number of capital-intensive automated brick plants have been established in developing countries. With the exception of the unskilled and semi-skilled labour, most of these plants encounter running and financing costs which are every bit as high as those in America or Europe and so would also realistically need to price their products at double the prices of the traditional unmechanised industries. This is hardly practicable for usages where traditional or mechanically-produced bricks are interchangeable, so the former always win on price. The higher price of mechanically made bricks is only justifiable where these bricks can fulfil special applications which cannot be served by traditionally-made bricks; loadbearing brickwork in high-rise buildings and acid resistant ware, for example. Unfortunately this type of application is far less frequent than the need for brick for ordinary housing, schools and industrial construction and so many of the mechanised factories which have been constructed have had to struggle to find markets and frequently run at only a fraction of designed capacity and usually at a loss.

Implications of alternative technologies

Capital intensive highly automated brickmaking has largely settled down into a familiar series of processes so that anyone well acquainted with the industry is likely to immediately recognise the same type of equipment installed in mechanised factories operating in, say, Australia, Germany or Algeria. There is an interesting correlation between the level of mechanisation and automation and the **scarcity** rather than the cost of labour. Once a capital-intensive factory has been decided upon it is a continual threat to the prosperity of the owners that the plant may not produce to its design capacity. The greatest single difference between the operation of capital intensive and labour intensive plant in financial terms is that in the former, most of the costs are fixed and are incurred whether or not any bricks are produced, whereas in the latter nearly all the costs are variable and once bricks stop being made the costs stop being incurred also. Managements will increase the level of mechanisation if they fear production holdups due to labour shortage.

The consumption of energy may not necessarily be lower for labour-intensive plant than it is for a capital-intensive one – particularly in the area of kiln firing, as the greatest economy of scale in brickmaking is the point at which continuous firing can be achieved. This point is somewhere in the region of 3 million bricks per year produced from a single site. As a result, examples of brick industry consumption of process fuel show some extreme differences:

	Nature of fuel	Approx calorific value per tonne (Megajoules)	Weight of fuel equivalent to burn 1 000 bricks (tonnes)	Heat needed to burn 1 000 bricks (MJ)	Capital cost of firing installation at 1978 costs and prices
Modern oil-fired tunnel kiln factory	Oil	44 000	0.11	4 800	£2 000 000
Traditional wood fired clamp brickworks (East Africa)	Firewood	16 000	1.00	16 000	£300

Achieving the higher degree of fuel efficiency requires an expenditure of almost two million pounds on the kiln and its building and services while virtually no capital investment is required for the clamp. If the possibility emerges of obtaining continuous firing with a much lower capital investment and with a more plentiful fossil fuel – coal, then the energy case for intensive mechanisation is eroded. As will be seen in the subsequent review of developing world brick industries, continuous firing is being achieved, sometimes in what are otherwise rather primitive conditions. Typical fuel efficiencies achieved are as follows:

Traditional coal fired Bull's Trench continuous kiln (India/Pakistan)	Coal	27 000	0.20	5 400	£20 000

Reasonable fuel economy is even achieved in many coal fired clamps provided they are built large enough and proper insulation measures adhered to:

Coal fired clamp (India, Turkey, UK, etc)	Coal	27 000	0.32	8 600	£1 000

The quantity of energy consumed makes the Bull's Trench continuous kiln, (described in a subsequent section from page 59 onwards), a very attractive proposition. The snag with this firing system as devised at present is the necessity to run the kiln with a fairly large volume of throughput which may suit market demands in the high population densities of the Indian subcontinent but may be too large for many other developing world locations. The most efficient clamp installations consume up to 50 per cent more fuel than a continuous kiln but have the advantage of being able to use a wider range of fuels, including a number of waste materials such as clinker which may be freely available in the local area.

Labour productivity

The other crucial determinant of a choice of technology is the amount of labour needed to operate it. Here again the difference between extreme mechanisation and extreme labour intensity is very large but so too is the range of efficiencies encountered in unmechanised brickmaking as can be seen in the following comparisons:

	Manhours required to produce 1 000 bricks		
	Process from clay pit up to and including formation of wet clay bricks	Process from commencement of drying operation to completion of fired bricks	Total
Most highly automated brick plant USA	0.4	0.6	1.0
Moderately mechanised brick plant UK	3.5	1.5	5.0
Traditional slopmoulding and clamp burning, Lesotho	16.0	15.0	31.0
Traditional slopmoulding and clamp burning, (including fuel gathering) Tanzania	14.0	40.0	54.0
Sandmoulded brick production semi-traditional, Sudan	32.0	30.0	62.0
Traditional slop brickmaking, coal fired clamp, Turkey	16.0	16.0	32.0

In the most extreme instance of high labour use described at the beginning of this section, a plant was using 18 men to produce less than 1 000 bricks in a day and accumulating the very high labour use of 167 man hours per 1 000 bricks. It can be seen from the range of results in the above table that these more efficient traditional brick plants achieved between three and five times the labour productivity of the worst known example. This is a further indication of the very wide scope that exists for improving the technologies of brickmaking in developing countries.

Economics of choice – operating flexibility

A crucial factor influencing the choice of technology to adopt for a new factory in a developing country (or for that matter in any country) is the likelihood of a steady demand for the products. It is the misfortune of most conventional brickmakers that they operate facilities which perform best technically and financially when run at a constant output, while their customers in the construction industry are more than usually prey to economic cycles and varying interest rates. Every time a surge in building activity takes place, the brickmaker is besieged with customers who cannot understand why it is not possible to simply increase production to meet their demands. The labour intensive, low capital production unit is in a better position to respond quickly. This type of unit can, by quickly taking on labour and fabricating more moulds and other simple equipment, achieve an increase in bricks for sale within six weeks or two months. On the other hand, a mechanised installation may have a lead time as long as two years between the decision to proceed and having more bricks to sell. The design, construction and commissioning of heavily mechanised brickmaking plant and especially the kiln, is a lengthy process and rarely goes completely smoothly.

The lack of flexibility in capital intensive brick manufacturing hurts most, however, when markets turn down. The established feature of an advanced technology brick plant is that the majority of its costs are incurred just the same even at times when output varies. In other words the factories have a high element of fixed costs and even some of the variable costs such as the skilled labour controlling kilns, are in effect fixed unless the plant actually closes down.

High fixed cost plants are extermely vulnerable if the market for the products fluctuates, as construction markets tend to do. What seems to have happened in a number of instances of mechanised plants built in developing countries was probably never anticipated in the feasibility studies before they were set up; ie what happens in times when the plant cannot sell all its output?

Nearly all the advanced technology brick plants in both developing and western countries are based on single kilns or two kilns. These units are designed to run at a set output and so there is little flexibility in production levels. Indeed the high fixed cost element makes it essential to run at maximum output to keep unit costs down. However, in periods of low market demand, which could be caused by political upheaval or a transport fuel shortage or simply an economic recession, the brick plant has to go on producing up to 100 000 bricks a day. Each unsold day's production occupies 40 square metres of storage space which in times of severe recession has to be extended at a considerable capital cost while all the time operating costs also rise in the extra forktruck distances involved as the stocks extend.

What happens next is an attempt by management faced with cash flow difficulties to economise on operating costs. The only significant ones which are not fixed are those associated with production and maintenance labour, and maintenance material and components. Almost inevitably such economies begin to affect the plant's ability to sustain its designed output. When output falls, fixed unit costs begin to rise which in the case of the heavy capital plants usually results in overall unit costs going up in spite of the economies in variable costs.

Faced with higher total unit costs, management then feels obliged to try to recoup part of these from the market by raising prices. However, a building recession is the wrong time to raise prices and customers tend to turn to alternative materials or revert to using the products of the traditional producers. It is when sales of the mechanised plant begin to fall at this stage that the real crisis begins. Stocks get out of hand and management is forced to reduce output by shutting down one kiln if two were installed or, if only one, running it at half speed which means that nearly as much fuel is still used but for a reduced quantity of bricks.

A heavy capital brick plant running at half the designed output frequently incurs total unit costs 70 to 80 per cent higher than when run at normal output. Privately operated units generally close down after working for a time under these conditions. Whether or not public money was involved in the original investment, state takeover may follow but whatever public corporation is involved, it rarely stands much chance of putting the factory back on its feet. This is because during the running down period essential staff will often have been lost and extensive damage done as a result of forced economies on essential maintenance and other services.

The traditional plants during this time will have suffered an equivalent drop in demand level but their reaction will have been entirely different, which accounts for their resilience. A most notable feature is common to the traditional brickmaking industries which exist across the world in, to name just a few examples – Malawi, Sudan, India, Indonesia, Honduras, Mexico, Turkey, Egypt and Lesotho. This feature is that the brick plant owners do not expect to keep going at the same constant output. In fact the brickmakers in most of these countries mentioned operate only seasonally anyway and stop production during the rainy season.

Having very little in the way of fixed costs to worry about, they only restart making bricks if they feel fairly sure there will be a waiting market. Such a policy does not work to the benefit of the building trade which in many countries puts up with a period of severe brick shortage while waiting for the traditional producers to make up their minds that the rains have stopped and it is safe to make bricks again.

The essence of the resilience of the traditional brickmakers and their survival when normal commercial undertakings would have gone to the wall, can be summarised as follows:

While most mechanised units are utterly dependent on supplies of energy and spare parts, all usually imported, many traditional brickmakers can keep themselves going, obtaining their own supplies of firewood for fuel, and making and refurbishing most of their own simple production tools.

Stockpiles of finished bricks do not need to be expensively managed and provided with extra facilities. Instead, the inventory could just consist of fired clamps of 40 000 or so bricks, left to stand without further attention until the market requires them. It is even possible to stop outflow of cash before a clamp is fired, by leaving it with the bricks still in the dry form, sheeted down for protection against rain.

Although the labour laid off from a traditional plant will suffer hardship during times of low market demand, they do not usually expect or completely depend on the employment and can drift into other work until things improve. This is certainly preferable to the brickmaking operation going out of business completely.

During a time of crisis and prolonged market stagnation, if all else fails the traditional brickmaking undertaking can simply disappear and lie dormant. The only indispensible commodities needing to be preserved intact are the technical knowhow and management ability of the individuals concerned, which can be applied to bring about the reappearance of brickmaking when conditions again become favourable. Meanwhile the mechanised plants being dependent on a complex combination of resources being present to operate at all, will frequently have to be written off.

The most commendable feature of the traditional brickmaking industries therefore is that they regenerate spontaneously. Only in occasional instances have general market conditions or the arrival of mechanised brick production eliminated the traditional operator. Where this has happened the culprit has usually been the sandcrete block which is easier to make and quicker to build with and in the past was often cheaper, prior to the effect of the energy crisis on the price of cement. Since the time of the big rises in the cement price there has been a notable revival in some traditional brick industries and attempts to establish new industries by many countries where brickmaking has died out in the past, or never existed at all.

Economics of choice – quality and pricing

Offsetting their advantages of flexibility and survival ability, the traditional brick plants have a bad reputation for quality, which is perhaps understandable for industries which in some cases have operated for 50 years or more without technical controls or R and D input. Variable quality reflects on price and in some countries, the traditional sector's burnt clay bricks are bought for as little as a half or a third the price of a machine-moulded concrete brick, simply on the grounds that the other product is more regular in shape and more predictable in performance. In industrialised countries the position is usually reversed with the common concrete brick valued much lower than clay facing bricks.

Accordingly, the aspirations of any organisations investing in a highly mechanised brick plant might in the present circumstances be that a regularly shaped, extruded-wirecut burnt clay brick would overcome its cost disadvantages by commanding a far higher price than the traditionally made product. Unfortunately however, many plants have been bought on the assumption that with their enormously superior productivity they should make bricks more cheaply than the traditional suppliers can. This will only be the case where basic labour costs are more than about £2.00 per working day or 25 pence per hour at current factor costs. As described earlier typical wage rates in the countries considered are very much lower than this. Where labour costs are lower than £2.00 a day, an investment decision to opt for a heavily-mechanised brick plant will only be valid if labour is scarce, or if the apparent quality of machine-made bricks puts a large premium on their price. The second justification of course evaporates if it can be shown that labour intensive plants can produce the better quality bricks demanded by the market. It is one of the central purposes of this study to investigate the factors which lead to the poor quality of most of the Third World traditional brickmakers' products. To identify means to upgrade quality without greatly altering the basic nature of the traditional plants, could significantly benefit both brickmaker and customer in developing countries.

Brickmaking at the most basic level is a straightforward technology, not without pitfalls but one which can be reproduced on a very small scale. To find the answer regarding the appropriate level of capital technology to incorporate in a new brick project, the most practical approach is first to set up a small pilot plant, employing three or four men making about 500 bricks a working day. This is because the quickest and cheapest way to determine whether a raw material is suitable for brickmaking may be simply to make a brick with it, rather than invest in elaborate and time consuming laboratory testing programmes. These would only need to come later if market needs, or the cost or scarcity of labour called for a heavily-mechanised brickmaking project – with expenditure of a million pounds or so it would be unwise to proceed without detailed prior examination of clay deposits. However for most projects, a pilot plant actually making bricks should supply all the necessary information including a realistic simulation of production economics.

PART C. BRICK PRODUCTION DEFECTS

Method and approach

In the description of brickmaking processes in developing countries, frequent reference will need to be made to defects in raw materials and production processes which result in poor finished bricks or outright loss. Rather than attempt to analyse the technical background to each fault each time it occurs in the commentary, it will save time and much repetition to devote a prior section to the subject of production defects and how they occur.

For a relatively simple object, a clay brick can incorporate a remarkable number of defects which in turn detract from the product's ability to carry out its functions in its end-use in a built wall.

The **quality** required of a brick depends upon the use to which it will be put and is well described in British Standard 3921 : 1974.

> '**Internal bricks** described as internal quality are suitable for internal use only and may need protection on site during winter'.

> '**Ordinary bricks** of ordinary quality are less durable than special quality, but normally durable in the external face of a building. Generally they do not need protection on site when stacked during one winter'.

> '**Special bricks** described as special quality are durable even when used in situations of extreme exposure where the structure may become saturated and be frozen for example in parapets and retaining walls'.

Problems of frost on brickwork only affect a few developing countries such as those with mountainous regions, but the extremes of wet and dry season climates elsewhere can equally well disintegrate the faces of substandard bricks as can be observed for instance in Ghana and the Sudan areas with no frost.

The **Class** that a brick is categorised into relates to average compressive strength. These range from Class 1 – 7.0 N/mm^2, adequate for non load-bearing brickwork applications in single storey buildings, to Class 15 – 103.5 N/mm^2, able to withstand massive compressive loads, for instance in the footings of very tall masonry buildings. Not only the compressive strength of a brick is important but also shear strength, a factor not always included in standard specifications. A brick of insufficient shear strength to withstand some degree of load will be suspect as a tie between the two 'skins' of a 225 mm brick wall and will also create weakness in the wall adjacent to openings. BSS requirements relate to the UK but in LDCs most building designs do not assume availability of strong bricks and compensate accordingly. For economy in application, other factors are of importance, namely regularity in size and shape. It takes considerably longer to lay mis-shapen bricks or bricks whose dimensions are inconsistent. Moreover, such products effectively increase the size of the gap between the bricks which involves a significant increase in cost in countries where high cement prices make the price of standard mortar considerably greater than the equivalent volume of brick.

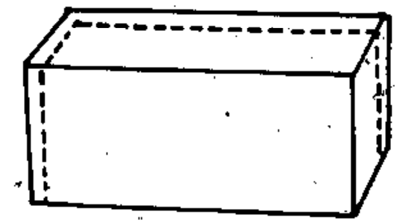
The following catalogue of defects is probably not fully comprehensive but should cover the main recurring faults which are a problem to the various brick industries and their customers. Some defects will occur only with one type of production process, such as extrusion wirecutting or slop moulding, others can occur in any type of bricks. Other faults may derive from inherent properties, physical or chemical, of the raw materials used. Unless the effects of these properties can be overcome by alterations to the process, they will be disregarded as irrelevant to this commentary as it is an entirely different field of investigation to devise how to make reasonable bricks out of normally unsuitable materials. Fortunately brick earth of adequate properties is one of the world's most plentiful materials.

The main classifications of defects are those of size, shape, compressive strength, shear strength, durability and appearance.

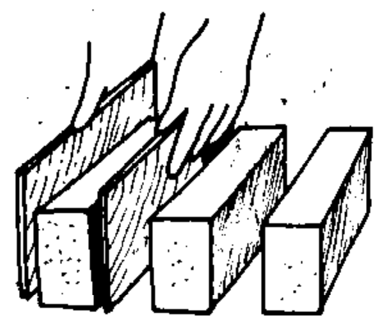
Defects of size

As a rectangular prism, a brick has three dimensions any one of which is liable to vary as a result of faulty processing:

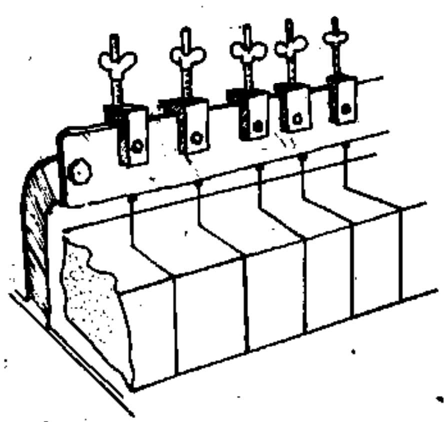
A brick which is **oversize in all three dimensions** is usually the result of a raw material or a firing fault. With the raw material the fault will probably lie in the proportion of coarse as opposed to fine particles in the soil. The presence of more sand and less clay will reduce the extent of drying and sometimes firing shrinkage of the brick. In plants where bricks incur firing shrinkage as a normal part of the process, an oversize brick will usually indicate that it is underfired. This will be confirmed if the brick is also lighter than usual in colour and has a duller than normal 'ring' (the sound made when two bricks are knocked together).



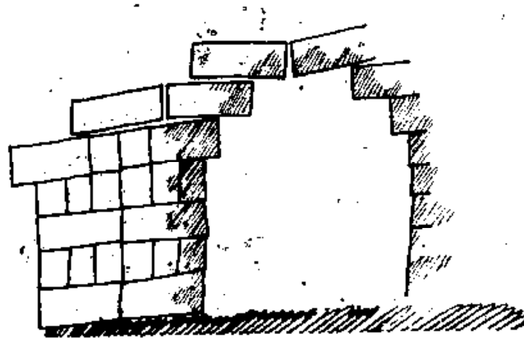
If the brick is oversize only in **width and length**, while the thickness is undersize, this will imply that the brick has been inadvertently squashed while still wet. This could occur in the sand-moulding process when the bricks are being set down on the drying rack or floor. It can also occur in the slop-moulding process if the brick drops out of the mould and the operator presses it to flatten out the distortion thus caused to the shape. Extruded wirecut bricks will not usually suffer this combination of dimensional faults.



Oversize in **thickness** only. This fault frequently occurs with extruded wirecut bricks. In the cutting process a long length of extruded clay is forced sideways through a row of wires. These are frequently set at incorrect intervals leading to irregularities in the thickness dimension. If the other two green-size dimensions are too large, this should be a result of wear in the extrusion die and will be accompanied by some distortion of the rectangular cross-section.



Those bricks which after firing turn out to be generally **undersize** in all dimensions can be the result of several process faults, including the obvious mistake of using undersize moulds or extrusion dies in the first place. Most likely, is inconsistent mixing of the material from the quarry face with too high a clay content in the batch concerned or the addition of too much water at the mixing stage. In either event the undersizing will show up by the end of the



drying stage usually in conjunction with other faults. Bricks can also become undersized during firing due to over-burning. This frequently occurs with the bricks around the firing tunnel of a wood-fired clamp which should be selected out as a separate grade.

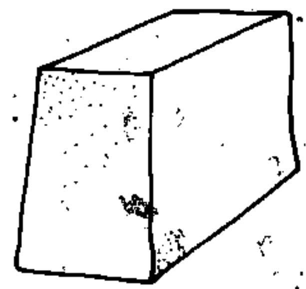
Defects of shape

There is a multitude of ways that a brick's shape can become distorted during the production process and the following description covers only what are regarded as the faults most likely to occur in developing countries' brick plants.

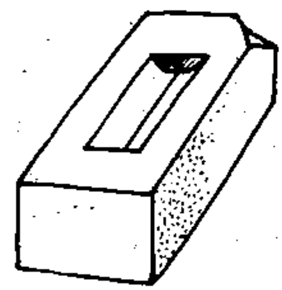
Slumping – if one stretcher face of the brick is wider with a slight bulge running the length of the brick, this is because,

(a) the brick was too soft in the first place and so the bottom spread as a result of pressure from the material above, or

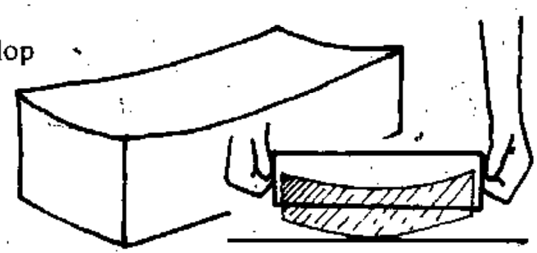
(b) the person handling the brick while wet, set it down too roughly.



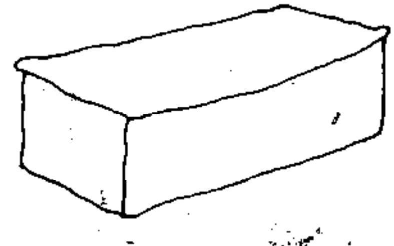
Rounded corners – the usual cause of a missing corner is a mistake by the moulder who failed to press enough clay into the mould box to fill it completely. Brick corners are also lost during rough handling while they are in the dry state and are particularly brittle.



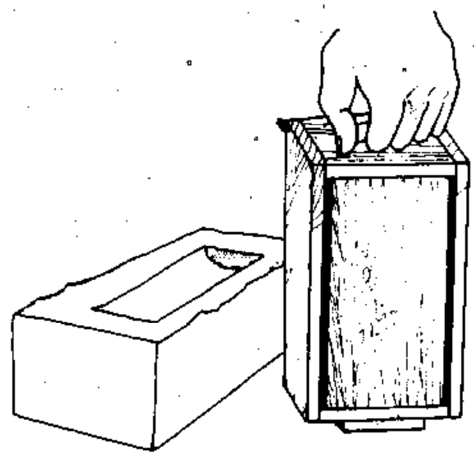
Raised corners – this is a common defect in slop moulded bricks caused by the corners of the brick sticking in the mould during the release movement.



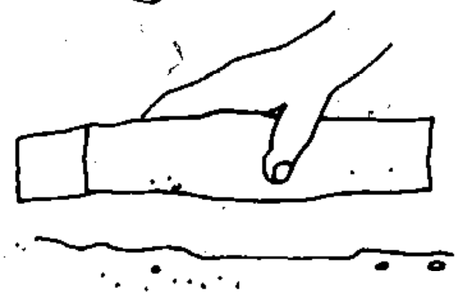
Lip on bed face – this is another moulding fault caused by the moulder not striking off the excess clay cleanly enough and leaving a 'flashing' around the edge.



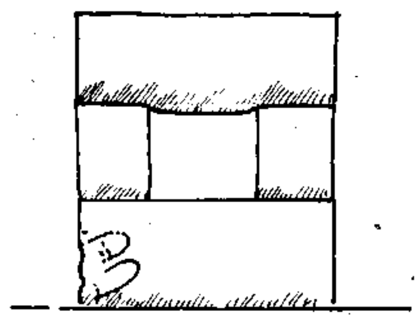
Flashing on sides of top face – this fault occurs with the use of fixed bottom moulds usually in production of frogged bricks. The spaces left down the sides to allow air to enter the bottom of the mould are sometimes wide enough for clay to protrude. This defect has been eliminated with the development of the hinged-bottom mould but these are not yet in widespread use.



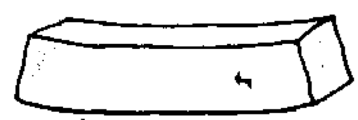
Distorted or contaminated under-surface – one of the main causes of imperfections to the brick shape is the drying floor not being smooth or covered with clean sand. The irregularities of the floor are transferred to the brick and any loose lumps of clay or pebbles in the sand become attached to the brick. These faults occur mainly when the bricks are set down flat with the slop moulding method.



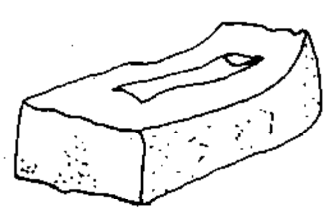
Stacking marks – bricks are frequently transferred from drying singly to drying in hacks in order to clear space for new production, and it is a common fault for this to be done too soon while they are still plastic, especially on the underneath face. When this happens the bricks incur finger marks and also distortion due to pressure of other bricks in the hack.



'Banana shapes' – differential rates of drying from one side to the other often distort the brick shape to the extent that it actually curves. This defect often rectifies itself automatically when the drying spreads across the brick, but if the top part of the brick becomes fully 'green hard' before the bottom has shrunk, the distorted shape remains. This problem can be avoided by gently turning over the bricks during the initial drying phase before the top side has dried completely hard.



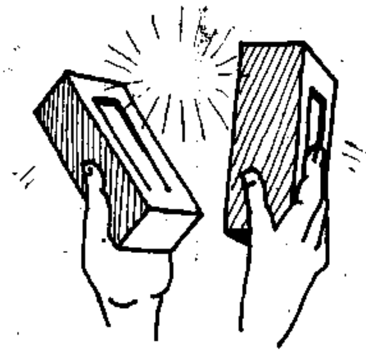
Multiple distortions – some bricks inevitably emerge from the production process twisted and generally deformed. This may have happened at the forming stage while the brick was being shaken out of the mould and such a brick should really have been rejected before the firing stage. Distortion can also occur with the overburnt bricks at the base of the clamp or kiln.



Defects of raw material body

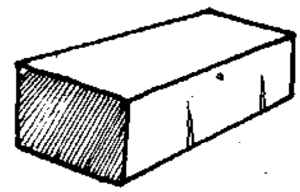
Some bricks although well enough shaped and accurately sized are still unsatisfactory because of defects in the body which cause them to be too brittle, soft or unable to withstand variations in temperature or humidity.

Underfiring – is one of the commonest reasons for bricks being unable to stand up to normal use and can often be identified when the brick is oversize (see page 10 above). Underfiring also shows in the colour of the brick which in normal red-burning clay is lighter than the well burnt bricks. The traditional test is to knock two bricks together; if the sound made is a dull 'clunk' instead of a metallic ring the brick is probably underfired and will have low compressive strength.

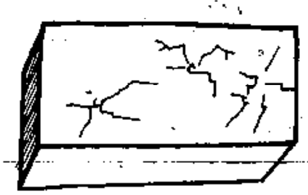


Visible cracking – also usually indicates that the brick is weak and may even fall apart during handling. Cracks can occur for a variety of reasons:

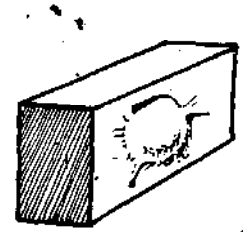
(a) Straight cracks extending at right-angles from one of the long faces of the brick happen during the drying process if this has been too rapid. These will make the brick liable to break even when the body is well consolidated and fired.



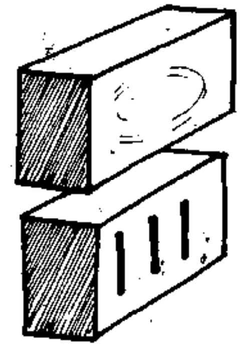
(b) Multiple surface cracks running in random directions are normally the result of differential drying shrinkage caused by the presence of lumps of drier material in the clay which do not shrink as much as the surrounding material. This fault arises from insufficient mixing of the clay before moulding or extrusion. Pebbles in the clay will have a similar effect and all of these faults will result in bricks with unsatisfactory shear strength.



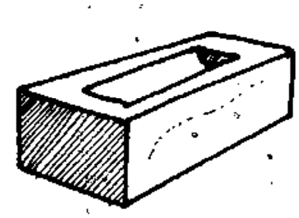
(c) Large cracks associated with a bulge in the surface of the bricks are signs of 'bloating' a fault which occurs when a brick is heated up too quickly during firing and the surface vitrifies before the chemical release of combined water or various gases from inside the bricks. Although misshapen, such bricks are often sound enough and can be used for applications such as footings.



(d) Extrusion laminations are defects which occur only in solid extruded wirecut bricks. The problem is due to the turning effect of the auger which propels the clay out of the barrel of the machine. The laminations occur where clay in the centre of the brick is being rotated faster than the clay on the outside. Laminations are a weakness and a laminated brick is particularly susceptible to frost damage or spalling when compressed. This problem can usually be overcome by inserting perforation dies into the auger mouth which restricts the turning movement of the clay.



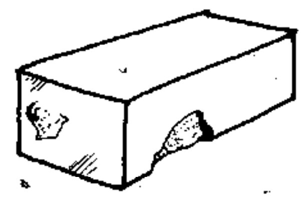
(e) Another kind of lamination crack can occur with bricks made by the sandmoulding process. This is caused when a piece of clay with sand covering its surface is inadvertently mixed into the clay of the brick. The film of sand separates the clay on either side of it so the brick will tend to split at this point if any stresses occur during drying or firing. The fault can also occur with oil moulding. Avoiding laminations from mould release substances is a matter of training.



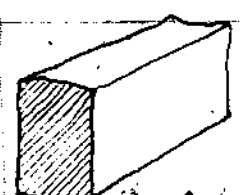
Defects of appearance

When bricks are to be used for facing applications it is important that the colour and texture of the surface should be fairly homogeneous and unmarked by obvious flaws. It is also a poor advertisement for bricks of alleged good quality to have obvious surface defects on the bed face even though this will not normally be seen in the brickwork. Several common flaws occur with both machine and handmade bricks:

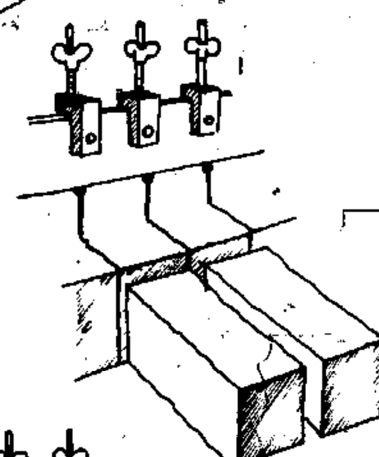
'Spalling' – a fault to which extruded bricks are especially susceptible but which can affect other bricks as well. This occurs during the early phases of firing the kiln when drying is still taking place. If the bricks are warmed up too quickly when residual absorbed water is still in the clay body, this will turn to steam inside the brick and explode, blowing away part of the surface, the process known as spalling.



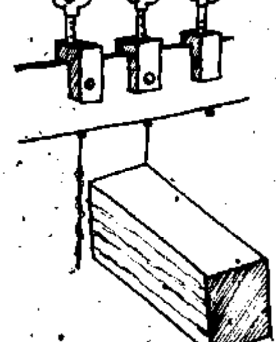
'Dog-eared' corners – are a common fault with extruded bricks and are caused by poor lubrication of the clay column as it emerges from the auger barrel. The defect occurs even with a well lubricated column if the raw material is too coarsely graded or badly mixed.



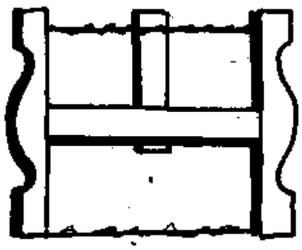
Ragged arrises – on the long faces of extruded bricks can also be a raw material defect but can also occur if the wires used for cutting the bricks in the side cutter are too thick or insufficiently tightened.



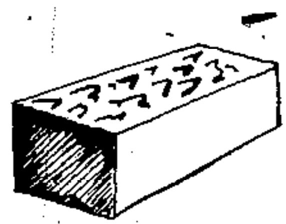
Drag marks – occur on the bed faces of extruded wirecut bricks when the cutting wires become clogged with twigs or leaves in the clay. They are unsightly and, when a particular large object becomes snagged on the wire, the drag mark can be deep enough to weaken the brick.



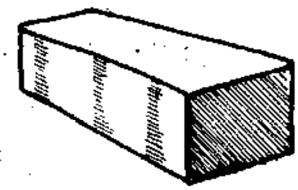
Similar drag marks can occur with sand-moulded handmade bricks if the bow cutter used to strike off the clay becomes similarly contaminated. Occurrence of drag marks on bricks is a sign that some topsoil is being mixed into the clay which is a practice to be avoided, as humus and other foreign materials can also affect the properties of the clay.

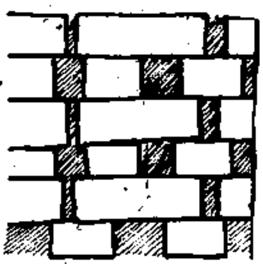


Another kind of drag mark occurs with slop moulded bricks when the moulder is removing the excess clay with his wooden or metal striker. This should be dipped in water before use otherwise it will pull and tear the clay surface.

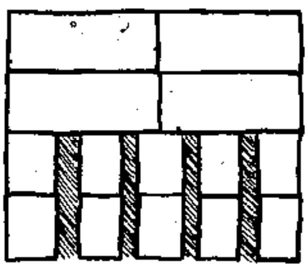


Barmarks – on the face of bricks can occur during the firing process with many types of raw material. If the preferred colour appears on the part of the face of the brick which is exposed to the kiln gases the remedy is to flat set the bricks so that all the stretcher faces are exposed. If on the other hand, the colour desired occurs only on the covered surface of the brick, they should be set face to face so that each brick has at least one stretcher face fully covered by another brick.





flat setting



'face' setting

Defects appearing after manufacture

The two most frequent defects which appear after manufacture and sometimes even after bricks have been delivered to site and have been constructed into buildings, are **efflorescence** and **lime-blowing**. Efflorescence appears as a crystalline deposit on the surface of the brick and is caused by soluble salts inherent in the clay or process water. The problem is usually a temporary one and should disappear with time, however, it can worry builders and cause complaints. In land which is intermittently water-logged, the salts will tend to rise to the surface of the ground and can be avoided by discarding the top layers including the topsoil itself. Otherwise there is little that can be done to prevent efflorescence except by adding expensive chemicals such as barium carbonate to the clay. Lime-blowing is a more serious matter and is caused by limestone lumps in the clay re-hydrating and expanding after firing. Batches of bricks can be checked for the presence of these lumps by 'dunking' in water prior to despatch. If lumps of sufficient size are present they will cause fractures in the bricks and pieces of surface to spall off, leaving powdery white lumps exposed. To avoid the lime lumps being in the clay in the first place, the material should either be ground or dry riddled and only particles under 2 mm diameter allowed to be incorporated into the process. Firing at very high temperatures can also eliminate the expansive effect of the lime which becomes 'dead' burned, but this procedure involves a heavy fuel cost penalty and is not possible for many clamp applications. Higher kiln temperatures can also remove some of the potential for efflorescence by turning soluble sulphates into more complex insoluble salts or by driving them off with other volatiles, but the brick industry does not readily incur higher operating costs for the sake of achieving this type of marginal benefit.

PART D. TECHNICAL REVIEW OF DEVELOPING COUNTRIES' BRICK INDUSTRIES

Scope of information

The information included in this section is not the result of any specially commissioned study tour of developing world brick industries, but more of a 'windfall' nature, using experience which has accrued as a result of technical assistance work in the countries concerned, up to 1978. The coverage is not uniform, is seldom comprehensive and in due course will become out of date. However, the depth of experience is sufficient to identify common themes and factors particularly in an assessment of recurring technical problems, which is the purpose of this exercise. The countries reviewed experience a fairly broad range of climatic conditions and employ people from contrasting backgrounds and widely different racial and cultural groups.

The review covers, in order, industries in developing countries in various parts of the continents of Africa, Asia, Latin America and the Caribbean.

LESOTHO

Brickmaking is a technology which is very widespread in Lesotho partially as a result of the influence of neighbouring South Africa where brick is the basic building material. However, the technology employed in Lesotho differs from prevailing South African practice being generally less capital intensive and producing bricks of lower quality standards.

The industry is made up of one or two semi-mechanical plants employing the extrusion wirecut process with a majority of traditional brickmaking enterprises using slop moulding methods for forming the bricks. All manufacturers dry the bricks naturally without use of heaters, fans or re-circulated gases from the firing process and they all fire bricks in clamps. The principle fuel used is clinker – ashes from power station and steam engine fireboxes which have a residual carbonaceous proportion which can be ignited when used as a layer between courses of bricks in a clamp. The same material is also added to the brick clay itself providing a carbonaceous ingredient to the clay body which burns out of the brick once a sufficient external temperature has been reached. Coal dust is also used for this purpose. Initial combustion is provided by burning coal or a mixture of coal and clinker in small hearths constructed into the sides of the clamps.

With the exception of two semi-mechanised plants, the Lesotho industry is a seasonal one having no facility to protect drying bricks from the rain. The biggest of the semi-mechanised plants dries its extruded wirecut products under drying hacks while a smaller adjacent plant has low roofed sheds providing a small amount of cover.

The Lesotho slop brickmakers dry their bricks in the open and although moulded bricks withstand the stresses of rapid drying far better than do machine-extruded bricks, heavy losses occur due to frost damage, cracking in the wind and sun, or when unseasonal rain falls. The open air technology also confines brick production to the dry season which creates considerable supply problems for the building industry whose activity is less affected by the seasons. This has probably been the main stimulus to the widespread introduction of cement blockmaking – with its attendant greater use of imported materials and requirement for transportation. Introduction of simple covered working and drying areas could overcome all of these problems and brickmaking could continue all the year round.

With their very restricted outputs, the smallest brickmakers cannot build a clamp which will burn a reasonable proportion of adequately fired bricks. Bricks placed near the outer surface of a clamp are inevitably less well burnt than those nearer the centre. The smaller the clamp the higher the proportion of bricks will be within a few inches of the outer surface. Ideally a clamp should contain at least 40 000 bricks whereas sometimes the small brickmakers fire as few as 4 000 at a time with consequential higher wastage and proportions of underfired bricks.

Diesel powered double-shafted mixer for clay preparation

Large scale clamp fired with coal and clinker waste from power stations

Side cutter producing wirecut bricks from an extruded column, installation partially in the open

Problems with fuel use exist with both the slop brickmakers and the larger and more capital-intensive extrusion plant. All bricks made in Lesotho are fired in clamps, there being no examples of permanent kilns. In simple terms, a brick firing clamp consists of a number of unfired dry bricks stacked upon a bed of fuel. The stacks consist of between 4 000 and approximately 150 000 and in cross-section are from 1.5 to 3 m high and from 1.5 to 4.5 m wide. When completed and before firing is started, the sides are covered with mud to prevent heat loss. During the rainy season the tops are covered with corrugated sheeting.

As well as the fuel in the bed, fuel is also spread between the bricks as the clamp is built. This source of heat is referred to as the 'externally combusted' or 'external' fuel. In addition to the external fuel, more of a different quality, called the fuel additive, is mixed in with the brick clay. Approximately 50 per cent of the heat requirement is supplied by each source.

Because of the different properties required the external and additive fuels must be of different qualities. To ensure good, even burning the former must be of coarse, lump material, whereas to keep the fired bricks as homogeneous as possible, the additive fuel must be of small particle size. The ideal additive fuel would have particle size less than 3 mm diameter. As a result of variable size and quality of coal and clinker added to the clay the fuel in some batches of bricks burns out almost completely leaving no ash residue in the bricks whereas that in other batches leaves a high ash residue in nodule size equivalent to that of the original fuel. These ash nodule inclusions cause lack of strength in the brick and are unsightly when protruding through its surface. These protruding nodules may indeed have a far more serious effect upon sales because of their resemblance to harmful lime inclusions which absorb water, expand and fracture bricks. Fuel considerations do not have a bearing just on quality and the question of which fuel should be bought for most economical operation is an important consideration for the brickmakers. Their tendancy to use clinker instead of coal is frequently not justified in the light of relative calorific values.

While the scale and level of technology of the small brick producers is regarded as too small, the more sophisticated, mechanised extruded-wirecut plants may go too far in the opposite direction especially for areas without ready access to skilled mechanics and appropriate spare parts. The process of most concern however, is in the drying system employed in Lesotho's semi-mechanised plants. The system originally established was to stack up the extruded bricks in drying 'hacks' – raised stands on which to position the bricks under a miniature roof that provides protection against rain and direct sunshine. This is standard procedure and fundamentally sound in most temperate and tropical locations. However, certain extreme conditions occur in the Lesotho climate with periods of very low humidity. The strong prevailing winds dry the stacks of bricks so rapidly and unevenly that large numbers crack. The remedy attempted by the brickmakers has been to protect the stacks of bricks by covering them with plastic sheets, intermittently lifted up when less harsh natural drying conditions occur. However, the drying time required for a batch of bricks now takes three to four weeks when it should really be less than a week (slop bricks dry in three days). Excessibly long drying cycles waste operator time covering the extra distances involved in moving about the large drying area and the upkeep of the sheets will be a heavy additional cost.

To summarise, the Lesotho brick industry's traditional production processes and the main problem areas are as follows:

Clay winning – Mainly a manual process using hoes and shovels. This is not a source of difficulty as the local raw material is fairly uniform and being friable, is easily broken up.

Slop moulded bricks drying in the open destroyed by rain

Stack of extruded bricks sheeted over to prevent drying cracks and also as a protection against rain damage. This procedure prolongs the drying period to 3–4 weeks

Clay preparation – This process is carried out using soaking pits in which the material is initially proportional in layers, together with the additive fuel and then turned over and over before leaving to soak. The procedure is a good one and further local development could turn the system into an effective clay preparation method. All that is needed is to ensure that the clay is dug evenly and the soaking period extended by a few days to ensure all the clay lumps break down into an even plastic body. What is unsatisfactory is the large size of the clinker lumps put into the clay which leads to defects in strength and appearance, (see Part C). The problem would be overcome by a system for crushing and screening the fuel lumps to reduce the particle size below say, 5 mm diameter. Some brickmakers have a problem transporting water to the clay preparation pit particularly by the end of the dry season when the streams have stopped flowing. A combined well and storage tank, possibly charged by a wind-powered pump would be a very welcome addition to the facility.

Brick moulding – The Lesotho brickmakers produce one of the better shaped slop bricks of any of the traditional industries in Africa. Their moulding method consists of a two piece mould equipped with a bottom frog plate. Each moulder has two sets of moulds. After filling the first set it is carried to the drying floor and put down in the drying position. The pallet is removed from under the mould and, by the time the moulder returns with his second mould set, the bricks in the first mould set are sufficiently loosened for this to be lifted off the bricks and taken for refilling. The moulds are painted inside which greatly assists the mould-release action. The work of carrying the brick moulds to the drying floor is excessively laborious and possibly injurious to back muscles, however, and another carrying system is required.

The distortion of initially well formed bricks takes place later during the drying period as is described in Part C. In their final dried form the Lesotho slop bricks are characteristically sunken in the middle of their long narrow dimension with a rough bed-face due to picking up material from the drying floor. These distortions would be overcome by switching to sandmoulding which would enable the bricks to be moulded more stiffly and to be dried on edge rather than on the flat.

Drying – Neither the traditional industry nor the semi-mechanised brickmakers have overcome the problem that a wet season/dry season climate causes for the brick drying process. With the former, the rains simply stop brick production while the latter have only overcome the problem of excessive cracking during periods of low humidity by extending the drying period to an unacceptable length with the use of plastic covering sheets. The drying problems of both industries would be overcome by construction of low cost drying sheds which would have the facility to permit or restrict the flow of drying air to accommodate for the varying levels of natural humidity.

Burning – The Lesotho brickmakers have achieved the best solution by opting for clamp firing of their bricks and, in the case of the semi-mechanised plants, the clamps are sufficiently large to achieve reasonable efficiency. However, no brickmaker protects the clamp sides sufficiently from cooling winds nor is the practice of insulating the side walls with mud and rubble adequate to achieve reasonable insulation against heat loss. As a result fuel consumption per 1 000 bricks exceeds 10 500 MJ, significantly higher than the more efficient clamp-burning plants elsewhere. In operation the clamps also experience problems in the initial stage of starting the fire. This activity requires use of an efficient hearth which maintains combustion without letting in too much excess air which slows the temperature rise. At present the hearth arrangement is rudimentary, using a removable grid of fired bricks which can hardly produce the best results.

Inter-process movement of materials – The use of wheeled trucks is fairly widespread in Lesotho brick plants. In particular, the standard wheel-barrow has been universally adopted. However, water is frequently carried rather than piped or moved in a wheeled truck and there has been little application of special purpose trucks and vehicles to handle bricks.

To conclude, Lesotho Traditional Brick Industry is one of the better developed of the African industries. No heavily capital-intensive units have been constructed although one is being contemplated by the development authorities. Labour productivity is fairly typical, being in the range of 30 to 100 man hours per thousand bricks. Major scope for increased efficiency and better quality exists in the moulding process, brick drying and in movement of water and materials. At a lower emphasis there is room for improvement in clamp firing and insulating methods but using techniques already known to brickmakers elsewhere.

MALAWI

The brick industry in Malawi has several similarities and some significant differences to that of Lesotho. The climate in Malawi does not have such extremes of low humidity as the mountainous areas of Lesotho so brick-cracking due to over-rapid drying is less of a problem. To fire the bricks, instead of using coal and clinker, Malawi brickmakers use firewood and so clamp building and burning follows a different system. An extrusion wirecut plant exists in Blantyre but this does occasionally have difficulty in marketing its full production capacity. By contrast the traditional handmoulded brickfields are active and apparently prosperous. Firewood appears to be a readily available resource and as a result clamps are well stoked and bricks are relatively well burned.

Moulding is again using the slop method and only in this area do the Malawi brickmakers produce worse results than those in Lesotho and then only slightly so. The brickmakers use single moulds and deposit bricks on the ground straight after filling the mould which frequently requires it to be shaken to release the clay with consequent danger of distorting the brick. However, most Malawi slop bricks are surprisingly well shaped for bricks of this type.

An interesting innovation has been introduced into the clay mixing stage in this country's industry. The clay workers use a tool converted from a standard hoe, which can pound as well as cut into the clay. This tool can be described as a 'hammer hoe' as it has a wooden mallet head on the opposite side to the hoe blade and can be turned over with a quick flick of the hands. Knowledge of this tool could benefit brickmakers in labour intensive plants in other countries.

Malawi brickmakers produce frogged, solid bricks which though frequently well-fired are variable in form due to the slop moulding and drying process. Women frequently work in the brickfields as in Lesotho, but the tendency is for them to work in groups whereas in Lesotho the moulding team often consists of just two people who work apart from the others.

Drying takes place in the open air – with the exception of the mechanised plant which has enclosed drying sheds mainly with concrete floors. The mechanised plant also employs wood fired kilns, or more accurately, a cross between an enclosed clamp and a scotch kiln. These kilns produce a more even burn than the clamps but at the expense of approximately 40 per cent more fuel, consuming 1½ tonnes of firewood for each tonne of ware. None of the bricks burnt are assisted by addition of any carbonaceous material to the clay and rely entirely on externally combusted fuel. This probably is a missed opportunity as many combustible waste materials exist in the agricultural community which could be added to the clay to reduce the firewood costs.

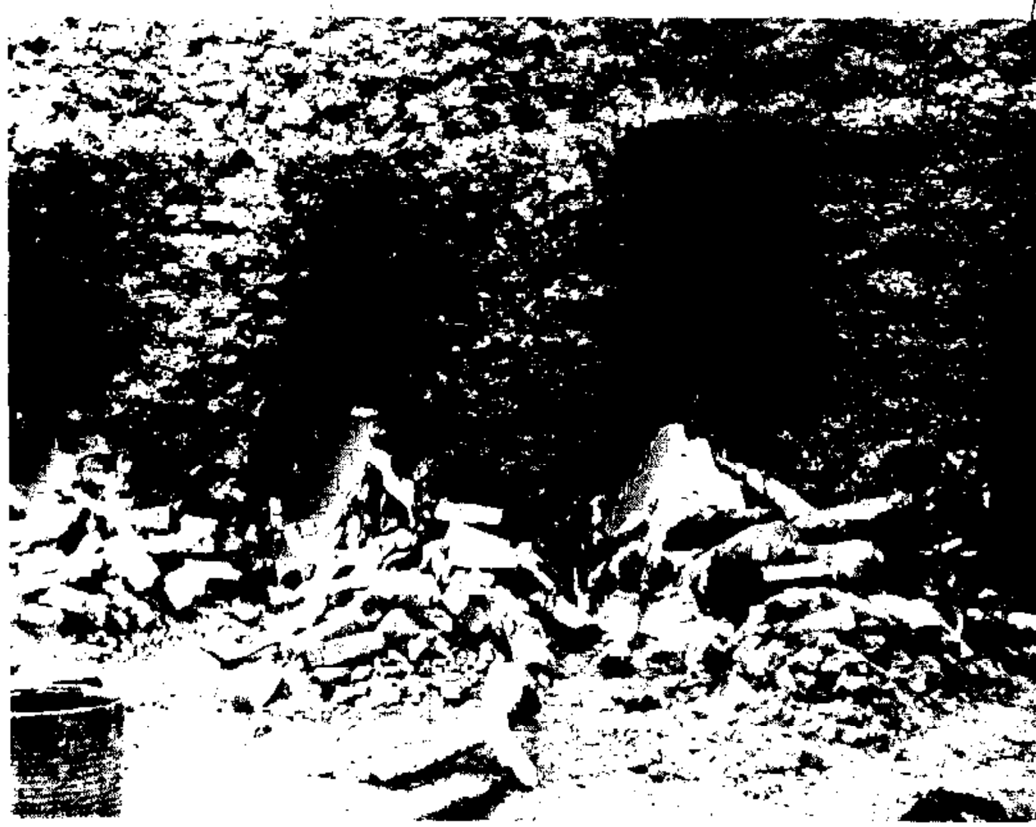
Woodfired clamp after burning showing large fire tunnels where wood is burnt

Products of extruded wirecut ceramic factory near Blantyre

Manual clay mixing in shallow pit in slop brickworks

Initially well-shaped slopmoulded bricks with only minor 'flashing' defects subsequently distorted by uneven drying floor

Wood-fired clamp under construction by lady brickmakers. Lack of suitable hand trucks leads to excessive carrying. Some shape defects can be seen in bricks in the foreground



Opening of fire tunnels permitting ingress of cold air with consequent wastage of fuel

The processes employed by the traditional industry in Malawi are summarised:

Clay winning and preparation – Using the hammer hoe as the basic tool, the quarry workers both dig the clay in the pit and also mix it ready for brickmoulding. Generally the clay is moulded directly after mixing which should only be possible with the easier clay materials and speaks well for the hammer hoe technique.

Brick forming and drying – Malawi's traditional slop moulders are unusual in their adoption of a fixed bottom single mould, similar to the sand moulding tool. The air gaps at the sides have to be fairly large to release the brick which produces a characteristic flashing defect along the arrises (see page 12). The drying grounds are seldom well enough prepared and transmit distortions to the bricks which would otherwise turn out as very well shaped, due to the skill of the moulders and the excellent moulding properties of the clay. The latter helps to produce good drying results but the lack of cover confines activity to the dry season.

Firing – The brickmakers around Blantyre are skilled in building and burning clamps and appear able to achieve higher temperatures in the fire tunnels than many producers in other countries. However, the clamps lack proper damping facilities to restrict the excess inflow of cold air and they also have insufficient insulation and protection against cooling winds.

Of the traditional brick industries reviewed, Malawi's appears to be the most sure of itself and competent to produce adequate bricks with rudimentary facilities. However, fuel consumption is greater than necessary due to the open clamp fire-tunnels, and seasonal constraints prevent brick manufacture from becoming a steady employment throughout the year.

ZAMBIA

The Zambian brick industry falls part way between that of Lesotho and Malawi in so far that both coal and wood are used as fuel, coal in the urban plants and wood in the rural area. The urban plants incorporate the use of coal-fired kilns, initially down-draughts but projects are in train to introduce continuous firing. These plants even produce an extruded wirecut 'engineering' brick with crushing strength above Class 4. By contrast the rural plants are known to produce generally soft fired bricks with only a proportion able to meet the normal requirement for common bricks. In a testing programme carried out in 1971 some sample bricks from Fiwila and Chipeso in Central Province and Kasama in the Northern Province, had compressive strengths below about 3.5 N/mm^2 although bricks of twice this strength were found in Chipongwe, Katete and Nyimba.

In other aspects of quality, Zambian rural bricks made by the slop process are generally mis-shapen without sharp arrises. This is due to the use of uneven moulds and poor moulding techniques together with lack of attention to the drying grounds which are often strewn with lumps of earth and vegetable matter which distort the bottom face and sometimes the whole brick as described earlier on page 12.

By contrast the problems with the urban bricks appears to be the high incidence of cracking which is a common fault with extruded wirecut bricks. The cause of this cracking was not fully identified although the likelihood was that this could be attributed to raw material preparation inadequacies and uncontrolled drying. To summarise, Zambia's brick industry has the following problems:

Clay winning – The urban plants' bricks are made from alluvium which has accumulated in the 'dambo' regions, small topographical depressions with relatively deep clay faces, up to 6 m. These areas are usually flooded during the rains which confines clay digging to the dry season. Handtools such as picks and shovels are used to dig the clay and load it into tractor-drawn trailers to move to the plants. The rural brickmakers use hoes and wheel-barrows but work from much shallower deposits and sometimes from anthills.

Clay preparation and brick forming The urban plants' extruded bricks are generally produced directly out of clay arriving from the pit and without prior weathering which could point to one of the causes of the excessive cracking. Alluvium needs little processing to reduce particle size and the main equipment used is the single and double shafted mixer prior to extrusion. Rural plants use hoes and treading for mixing the clay and leave it to weather overnight. They slop mould the bricks in double cavity moulds. Some producers actually sand these moulds to assist the release of the bricks but still lay the bricks flat to dry as do the pure slop moulders.

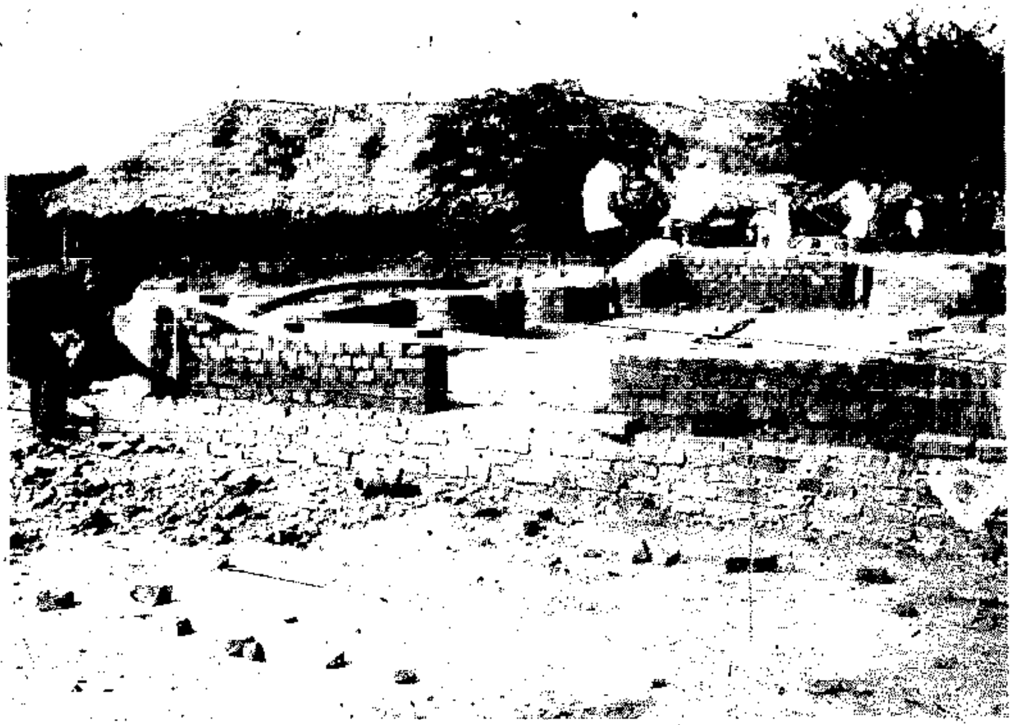
Drying – While the extruded wirecut bricks are generally dried in roofed hacks similar to the Lesotho pattern, the slop moulded bricks dry in the open on the ground. They are less liable to crack than the extruded bricks mainly because of a deliberate choice of much sandier clay by the producers and also because the brickmakers cover them with grass to slow the rate of drying when necessary. This open air procedure of course confines brickmaking to the dry season.

Firing Clamps are constructed to sizes sometimes as large as 100 000 bricks. Most of these are constructed in the open but one works has permanent clamp walls and a metal roof which permits firing even during the rains. Two of the urban works have permanent kilns equipped with temperature-recording equipment. The wood-fired clamps built by the rural brickmakers of course have no instrumentation and are smaller, about 20 000 bricks and differ in structure from the coal-fired clamps of the urban areas. Large firing tunnels are built similar to the Malawi pattern and the clay is fired without carbonaceous content. By contrast one Lusaka brick plant incorporates coal dust into the brick clay as occurs with the extruded bricks of Lesotho.

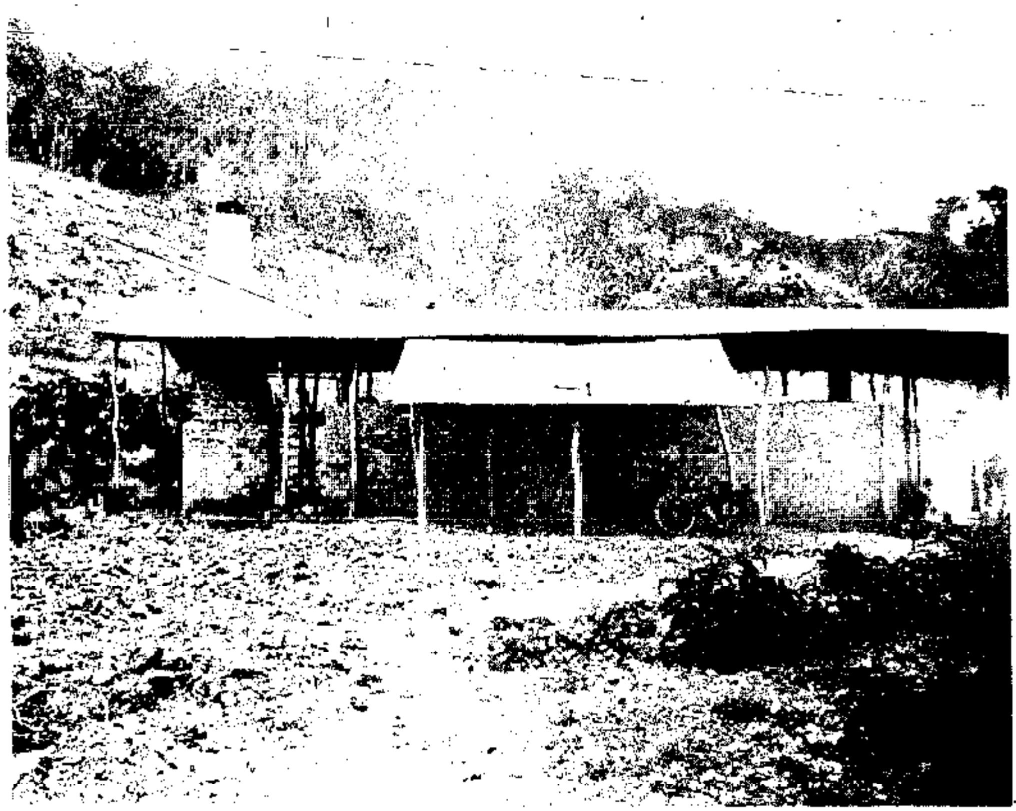
While the urban brick production process is evolving conventionally, along mechanised lines, the rural brickmakers are unlikely ever to accumulate the capital for this type of investment. Their development needs to concentrate around a better brickmoulding system coupled with a low cost all-weather drying system. Clamp burning technology also needs considerable improvement for bricks to achieve more acceptable compressive strengths.

TANZANIA

In the years following independence, Tanzania's brick industry almost died out in may areas of the country. This seems to have been due to lack of official support and in some instances the departure of Asian owner-managers of the mechanised plants. A rural brick industry remained active in the south of the country, usually in areas where missionary influence prevailed and some prison administrations maintained brick production in Morogoro and other centres further north. In recent years brickmaking has received considerable official encouragement and village cooperatives and youth organisations have set up production ventures while a government housing agency was given the difficult task of reviving the defunct mechanised plants in Arusha, Dodoma and Kisarawe near Dar es Salaam. A large fully mechanised plant has been ordered for Dodoma.



Locally designed kiln under construction, intended to be fired with waste oil



Wood-fired intermittent kiln at mechanised factory near Dar es Salaam

The new small scale ventures have mainly concentrated on the most basic slop brickmaking technology, air drying and wood-firing in clamps. The revived mechanised plants fire their bricks in intermittent woodburning kilns. In one cooperative venture on the outskirts of Dar es Salaam, an attempt is being made to fire bricks in a specially built kiln to be burnt with waste oil, but this is the exception. Discoveries of coal in the Mbeya area may in time result in this fuel being used for brick production especially in the more arid areas such as those surrounding Dodoma, the new capital city.

Many of the new brickmaking ventures are in the heavily populated Dar es Salaam and coast regions near the old capital and because of the greater spread of seasonal rainfall, brickmaking is only really practicable if some drying cover is provided. Accordingly, all of these plants have constructed corrugated iron roofed 'bandas', low sheds under which bricks can normally be safe from the spoiling effects of rain. This in turn makes it possible (though not easy) for brickmaking to continue throughout the year. In periods of high humidity drying becomes very difficult and production inevitably slows down through lack of space under the sheds.

Because the people are in a position of relearning a technology which had almost been lost, the current situation is understandably full of examples of spoilt bricks and wasted effort due to inexperience:

- selection of too refractory clays which do not fire properly,
- loose cattle walking through the rows of drying bricks,
- allowing ground water to run into the sheds during heavy rain,
- trying to burn bricks which are insufficiently dried,
- starting to fire the clamp before sufficient wood has been gathered to sustain the burn.

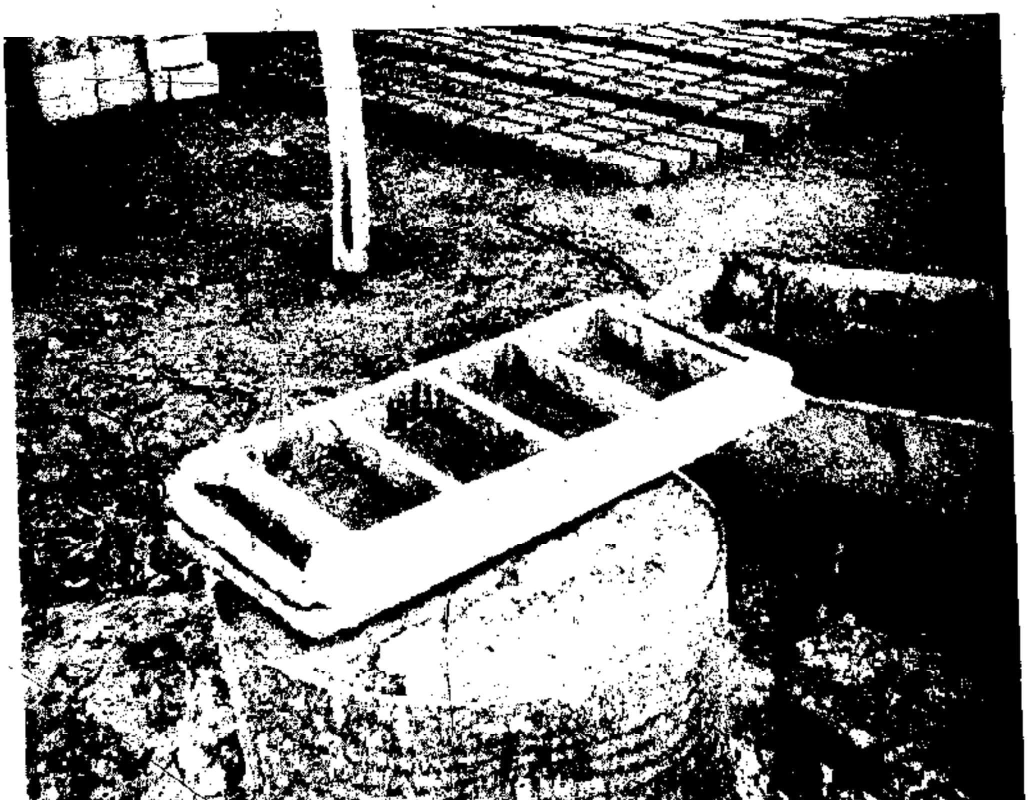
None of these can be considered long term problems which need fresh technical development to overcome, as more experience should eliminate these mistakes by the brickmaking teams themselves. Assuming these problems are overcome preoccupations are likely to turn to less disastrous, but still serious, operating defects of the same general type which affect brickmakers elsewhere:

Clay winning and preparation – Tanzanian brickmakers have to contend with a far greater variety of clays than do their counterparts in Lesotho, Malawi and Zambia. Moreover, many deposits have distinct variability between layers. To obtain a measure of consistency of mix, clay pits need to be dug vertically with each cut taking a full cross section of the face. With standard handtools there is a tendency to dig out a hollow of bottom clay and to allow the top measures to cave in subsequently. This inevitably leads to batches of bricks with concentrations of top clay or bottom clay in them and consequently different drying and firing characteristics and may cause the size problems referred to above on page 10.

Brickmoulding – Some of the early efforts at slop moulding in the new cooperatives' brick plants have produced some very irregular bricks. The projects in many instances have opted to use a four compartment mould which is very heavy to carry and to turn over on the ground and may be much of the cause of the quality problem. An opposite approach was taken at one new production/training plant where the brickmakers use a single, self-releasing mould in conjunction with the sandmoulding method and a better standard of hand-made brick is being made. The mechanised factories' extruded products are of moderate quality and vary with the experience of the operating teams. The main difficulty appears to be in keeping the old equipment going while breakdowns and spare-part delays often result in the whole labour force being at a standstill for several days.

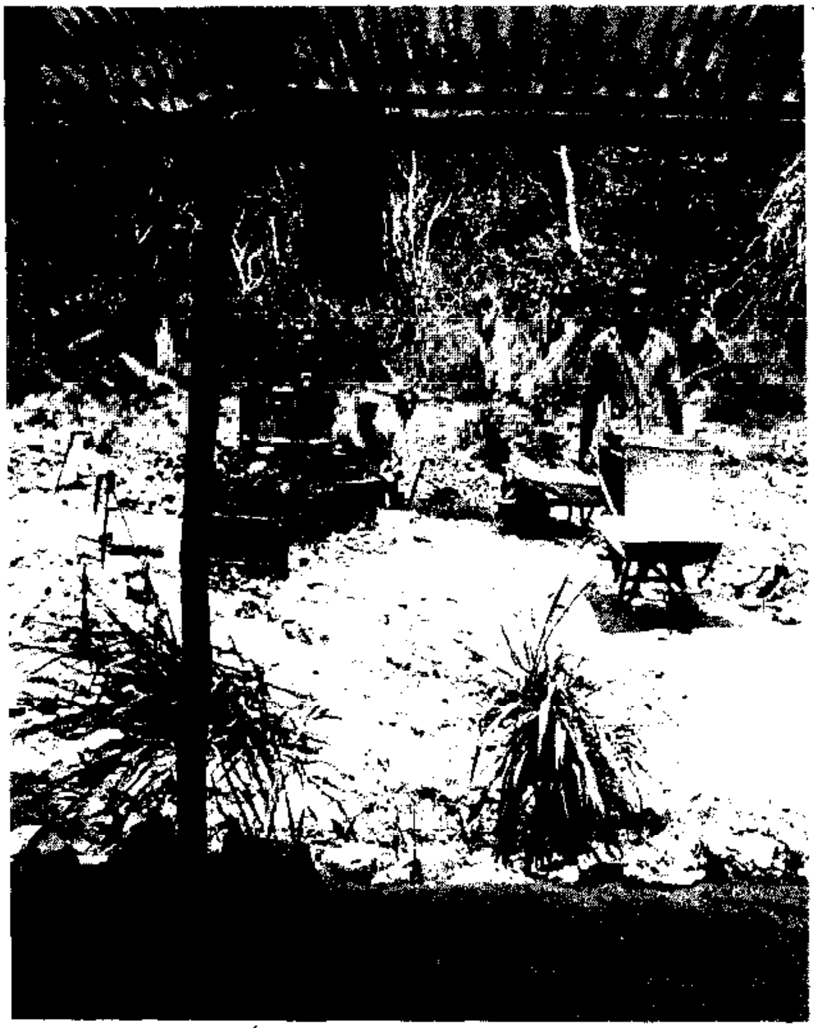
BRICKMAKING IN TANZANIA – MOULDING METHODS

Accurately sandmoulded bricks set out for initial drying. In the background, bricks are upturned to avoid drying distortion



Four-compartment slop mould – an unsuccessful technical innovation being over 20 kg when full and difficult to handle

Alternative system using single self-releasing mould in conjunction with the sandmoulding method



Improvised water transporting system with tub carried in wheel barrow – water supply is nearly ½ km away

Corrugated-iron roofed working and drying sheds constructed out of rough timber cut from adjacent forest. Buildings need provision to adjust for different ambient drying conditions

Clay preparation in pit using hoes and treading with bare feet – no proportioning system is available

Drying – The most common fault which may turn into a long term defect is the tendency of operators to handle bricks too soon and to stack them while one side is still plastic. Some of the plants work to a system of turning the bricks before moving them to stacks. This is the method advocated on page 12 to avoid distortions at this stage in the process. The next most important requirement is to make best use of the intermittent good drying conditions which occur during the rainy season. The slopbrick plants at Kimara and elsewhere avoid putting bricks outside at all during the rainy season. Use of a special handtruck at one new plant allows brickmakers to move stacks of 'green' hard, still damp, bricks out into the sun for final drying and to move them undercover again before nightfall or when rain is imminent. This can only be done where running surfaces remain hard enough for the trucks. No system is yet in use to accelerate the drying of still-soft bricks during humid conditions. This situation also prevails in the mechanised factories.

Firing – Tanzanian brickmakers' clamps are fairly crude affairs and no standard pattern has emerged for corbelling the fire tunnel arches or for the brick courses in the clamp superstructure. Much underburning is currently resulting from inadequate plastering and shielding of the clamps and the familiar problem of cold air entering the tops of the fire tunnel entrances wastes much of the fuel used. While firewood is plentiful in some areas, serious consideration needs to be given to using waste materials such as chaff and husks to provide a carbonaceous content to the clay. No work has yet been done to identify the appropriate proportions of these, by weight or volume, which should be added to the clay.

Much of the comment on the Tanzanian industry is more concerned with the temporary situation of inexperienced operators who will in time learn to overcome many of their basic problems. However, longer term problems over clay-winning methods, drying and firing still need to be solved with better equipment and systems.

NORTH AND SOUTH SUDAN

The brick industries of the Sudan follow a different technology depending on whether the plant is situated in the north around Khartoum and Omdurman, or in the south by the regional centres of Juba and Wau. Northern bricks are small with stretcher face dimensions generally under 200 mm in length and 50 mm in thickness and depend on the carbonaceous matter in camel dung for their combustion fuel. Traditionally made southern bricks are large with twice the stretcher face area and are composed of inert, sandy clay. The Southern Sudan brickmakers burn their bricks in woodfired clamps. Both traditional industries slop mould their bricks in wooden moulds but the northern bricks are far more regular in form than those made in the south and are generally harder fired. The northern brickmakers generally use double moulds while in the south a single mould is the basic brickmaking tool.

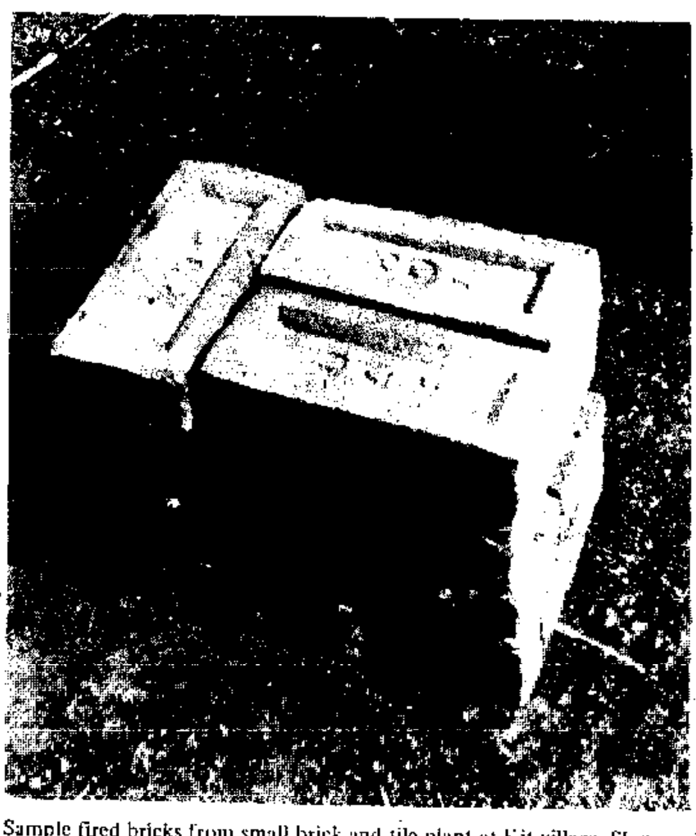
Availability of large quantities of camel dung is not a common feature of developing world brick industries nor is the use of this material as a fuel necessarily the most worthwhile application. As will be pointed out in subsequent sections of this report describing applications in Asian countries, animal dung is a valuable potential fertilizer and food production should have priority use. The ideal combination is to process the dung to extract methane which can then become the fuel source while leaving the principal nutrients behind in the sludge. However, no ready-made technology is available to extract methane from animal dung and burn it for brickmaking. Similarly, no technology is available for recovering the inflammable but usually wasted 'off-gases' from charcoal production. These gases constitute the major fraction of the fuel content of firewood and might well be turned into a gaseous fuel for an industrial process. This proposition is of potential significance in the Southern Sudan where deforestation is a problem round population centres due mainly to charcoal burning but made worse by the demands of brick production. A rationalisation of the two industries may be possible in some locations so that a given amount of tree cutting will produce a greater total value of bricks and charcoal than if the two were burnt separately.

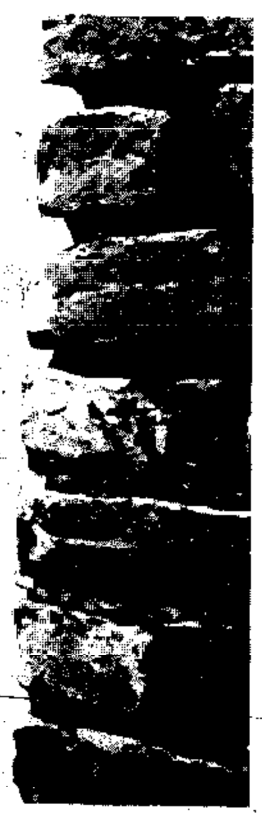
Covered working and drying sheds building in foreground built in traditional manner of round poles, bamboo and grass

More expensively constructed brickworks with two production buildings

Traditional brickmaking operations, clamps on open area near Juba

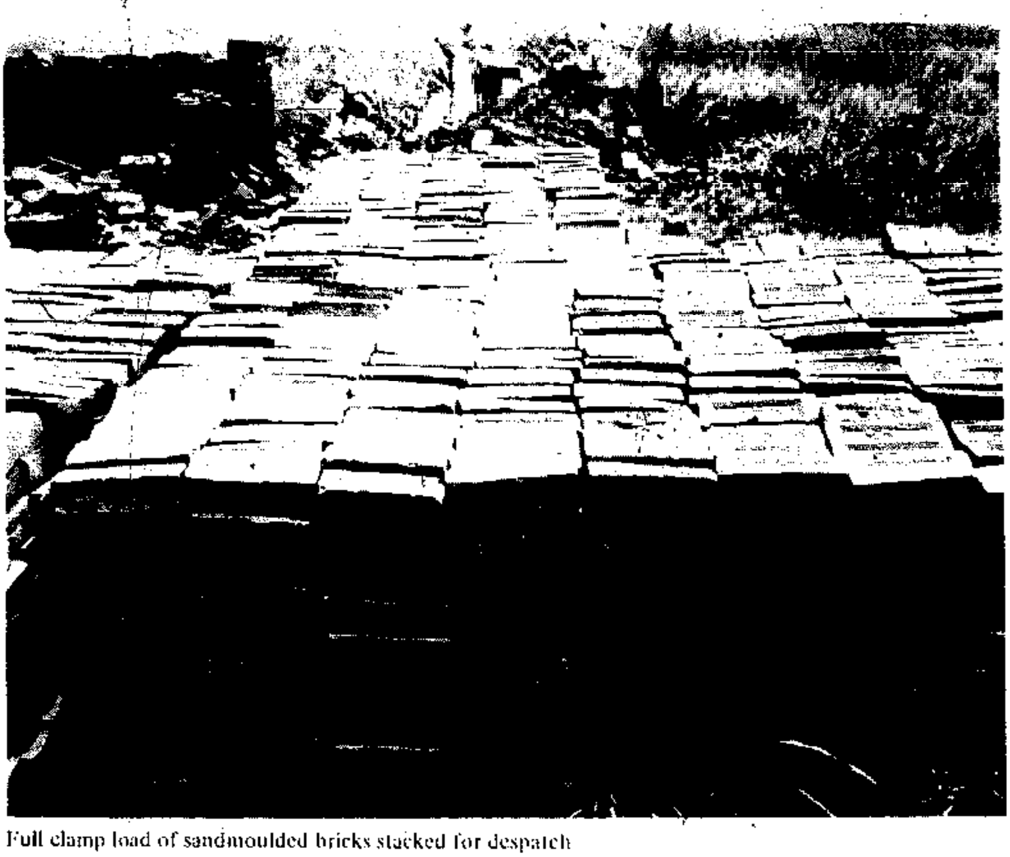
Self-releasing sanded mould in current use in Gumba brick factory





Sample fired bricks from small brick and tile plant at Kit village. Slopmoulded bricks made previously from clay shown in inset on right of picture

Additional cost incurred bringing sand to the brickmaking site if sand is not available in same location



Full clamp load of sandmoulded bricks stacked for despatch

The Southern Sudan's brick industry is far more typical of African brickmaking and in the traditional sector the familiar process of slopmoulding, open air drying and clamp firing is followed. The area has a long rainy season which has been known to shut down traditional brickmaking from April to November. This produces a situation of alternating brick glut and famine for the building trade for whom bricks are often unobtainable by the latter part of the rainy season. The business of slop brickmaking in the Southern Sudan therefore involves a difficult cash flow pattern, as by April, labour and fuel costs will have to be expended to produce a large stock of bricks, many of which will not be sold and paid for until the following September.

New brick plants are being set up along the same lines as the new plants in Tanzania, again assisted by external advice. These are based on the objective to continue production into the rainy season in spite of the intermittent high humidity and penetrating wind-blown rain storms which affect the area. The plants also incorporate sandmoulding with self-releasing moulds and a measure of mechanical handling, using manually operated trucks. At this stage however, the vast majority of the bricks in the Juba area of the Sudan are still produced by the slop brick process which can be summarised as follows:

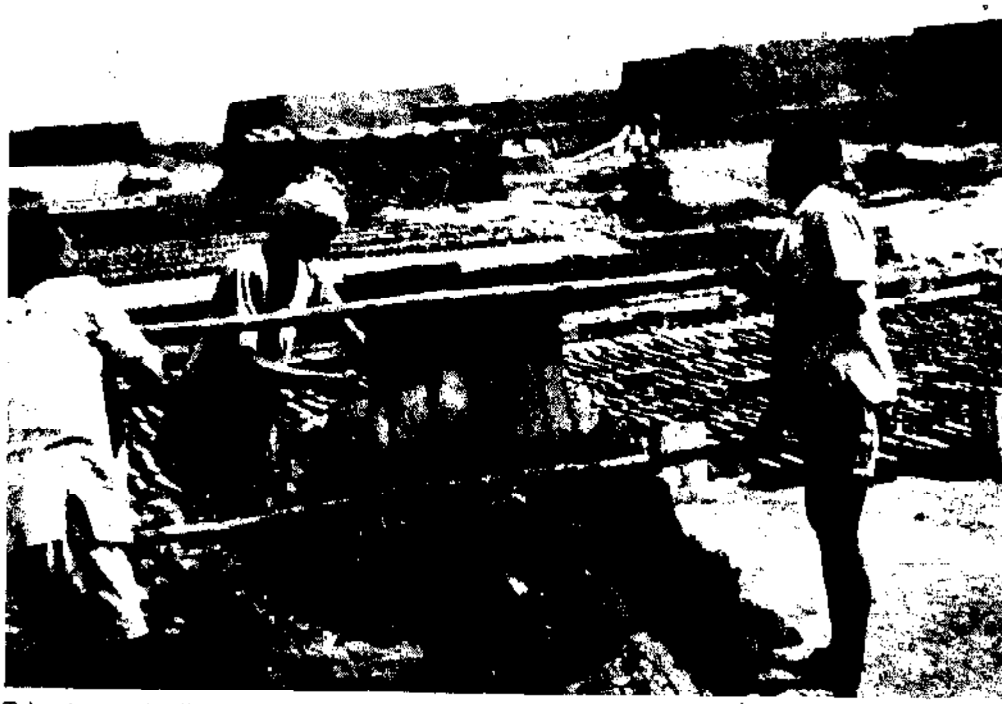
Clay winning and preparation – These are performed at the same time using hoes and treading with bare feet. The brickmakers normally choose the sandier clay deposits around Lologo because of the material's ease of moulding and lower tendency to crack with rapid drying, (the new covered plants at Gumba and Kit use more plastic clays in order to produce stronger bricks). One traditional brickmaker has however, recently set up production near the new Gumba plant. Water supply is a major problem for the traditional brickmakers when the water table is lowest at the end of the dry season. The facility to raise and store water would greatly improve their situation at sites distant from the River Nile.

Brickmoulding – Little care and attention is given to the moulding process and bricks are produced in a variety of sizes with most of the worst slop brick faults such as raised corners, lips on the bed face and distorted bottom faces described earlier in the report on page 11. By contrast the trained moulders at the new sandmoulded brick plants are producing adequately shaped bricks.

Drying – Initially, drying takes place with the slop bricks lying flat on the ground. Cracking is sometimes a problem in spite of the sandy clay and is probably the result of harsh drying conditions and intermittent strong sunshine of Southern Sudan. When this occurs the moulders cover the bricks with bundles of grass. As the bricks become 'green' hard, the brickmakers build the brick stacks up into small conical stacks for final drying. No cover is available and so if unseasonal rain falls the brickmakers lose the previous day's moulding output. The bricks inside the drying 'cones' survive which may be the reason for choosing this type of stacking arrangement.

Firing – As a contrast to their rough-and-ready moulding techniques, the Southern Sudanese brickmakers construct remarkably neat and compact clamps with a rectangular firing platform and tapered top. Some clamp builders actually construct a permanent surround for the footings using bricklaying techniques which simplifies the work of positioning the fire tunnels for each new clamp. The clamp burners also follow a strict burning routine, firing from one side and then the other and closing the clamp up once the top is hot enough to ignite straw. The difficulty of procuring fuel from the diminishing woodlands of the surrounding area causes them frequently to run out before firing is complete and it is not uncommon to see a partially burnt clamp of nearly unsaleable bricks.

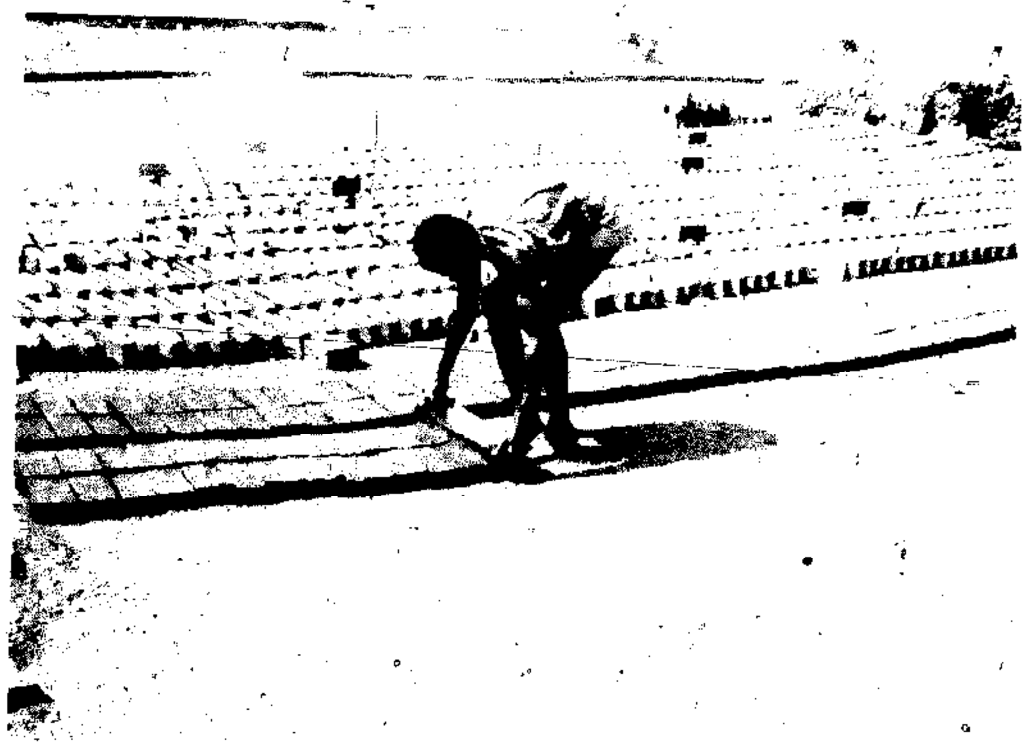
Clay dug and mixed with water, straw and camel dung at the river bank



Taken by carrying litter to the moulder

Moulder works with double compartment steel mould kept wet by dipping it in water trough

Brick carrier takes bricks in mould to drying ground



Brick carrier sets bricks on drying ground

When hard enough to handle bricks are stacked for further drying

When fully dry, loads of 50 bricks stacked on carrying litter

Two men carry dry bricks up to the clamp for setting

The major problem for the Sudanese brickmakers therefore is fuel. In the north, camel dung is no longer universally available and firewood to begin the burning is scarce and expensive. In the south the source of available firewood moves further from the population centre with each successive year. The clamp burning process is far from reaching optimum results and the same reason as before can be quoted — the need to have a hearth and grate which maintain the fire while preventing too much cold excess air from entering the brick setting. For the covered plants while production can take place during the rains, it will inevitably slow down as the drying period for the bricks lengthens due to high humidity. A technology is needed for taking better advantage of the available periods of sunshine and better drying atmosphere by, for instance, being able to move quantities of wet bricks outside and back under cover fairly rapidly to suit conditions. If bricks are set into clamps still wet, a significant proportion of the firewood is consumed finishing off the drying process which should have been done for nothing, using the sun and wind. Future development for the Southern Sudan may include a semi-mechanised plant currently being planned by the housing authorities, and the spread of brickmaking along the less-mechanised 'Gumba' pattern to other centres in the region.

GHANA

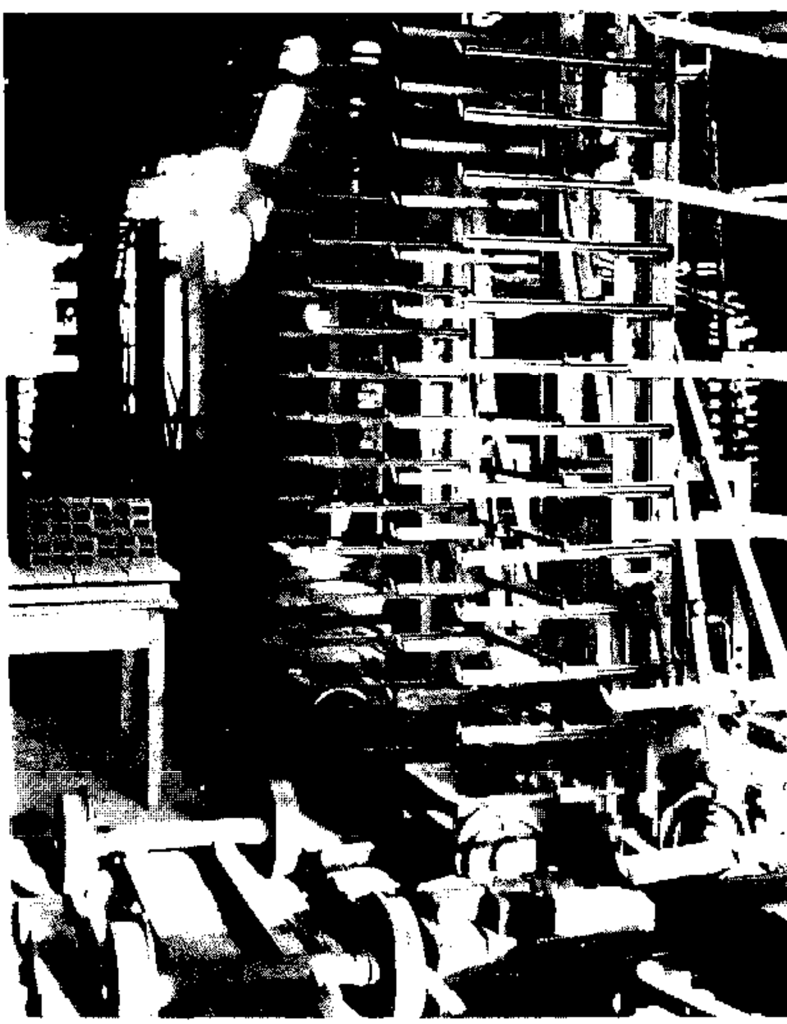
This country had a small brickmaking industry in and around Accra, Kumasi and Bekwai up to the time of independence after which production ceased except for that of a mechanised plant on the outskirts of Accra. This plant was equipped with grinding equipment, extruders, palletized drying and a multi-chamber, Hoffman continuous kiln. In the post-independence period the building industry was encouraged to use cement from the new grinding plant at Tema on the coast. However, the substitution of cement for burnt clay added to the import bill, as the Tema plant carried out only the last part of the production process using materials shipped from overseas. As a result, from 1973 onward, strong official encouragement was given to reintroduce brickmaking to the country which has resulted in numerous different schemes — none of which yet amount to a 'traditional' industry which is automatically being copied and initiated by local entrepreneurs or cooperative groups.

The scheme which is nearest to achieving this goal was based on an externally-assisted pilot brickmaking project constructed in Kumasi, which led to the establishment of larger scale plants in Asokwa, Ankaful and Fumesua. The plants are constructed and equipped from Ghanaian resources and make bricks by sandmoulding. Experiments have also been conducted with a locally developed press which makes two bricks at a time. Initially the clay was prepared by a small diesel powered single-shafted mixer, but this has now been substituted by foot treading to save the present high cost of diesel fuel. Initial drying takes place on wooden racks under cover of the roof of the production building and once hard enough to stack, the bricks are taken by manually powered trucks for drying outside in the sun, as is the practice in Juba, Sudan and Mwambisi, Tanzania. Bricks are wood burned in a specially designed side-fired kiln with double chambers and a central chimney.

Another series of brick projects has been based on imported mechanised equipment powered by a large diesel generator. These plants, at Sunyani and Kibi, produce an extruded air dried, wood-fired brick. Meanwhile, the original brickworks in Accra is undergoing a major re-equipping due to problems in keeping the rather complex machinery running. Similar to the Tanzanian experience, Ghana's brick industries' problems appear to be mainly temporary ones awaiting the gradual development of production skills needed to establish a brickmaking tradition to hand down, as happens in other countries. There are nevertheless some basic technical drawbacks which have not yet been fully overcome even by the most successful of the plants:

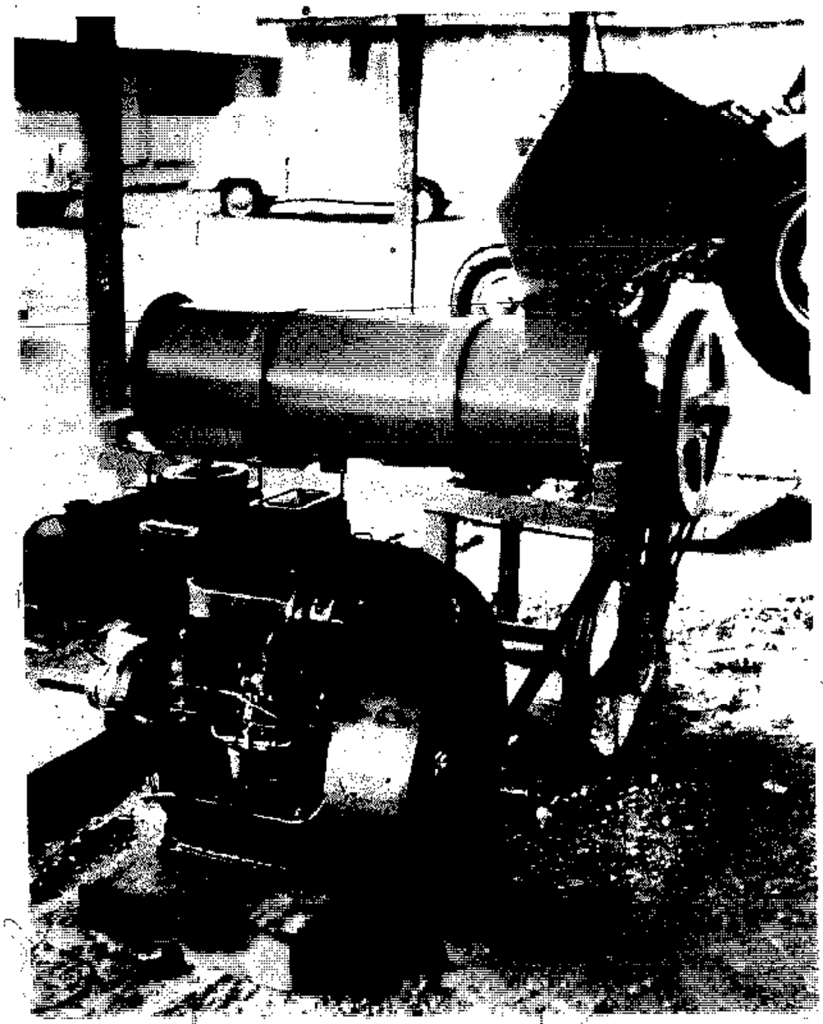
BRICK PRODUCTION IN GHANA – PREVIOUSLY ESTABLISHED MEDIUM SCALE PLANT, ACCRA

Well constructed Hoffman continuous kiln impeded in operation by hold-ups in brick supply from earlier stages in process



Example of rather complex imported brick handling equipment, frequently the cause of production delays

LOCALLY PRODUCED EQUIPMENT OPERATING IN GHANA BRICK INDUSTRY



Diesel powered mixing machine initially operated at Kumasi Pilot Plant and Asokwa brickworks. Use later replaced by manual mixing because of rising fuel costs

Ghanaian designed brick press similar to Cinva-ram experimented with in rural brick plants in the attempt to replace handmoulding

5

An originally constructed, side-fired double chamber kiln specially designed for wood firing, in use at Asokwa and Ankaful brickworks. Fuel consumption was high because the kiln is intermittent and no heat is re-used from the bricks cooling down from previous fire. Subsequent measures applied to increase the height of the side walls are understood to have improved efficiency

Clay winning – Manual digging of deep clay faces at some rural plants if unsupervised will inevitably lead to irregular batches of top and bottom clay and variations in brick size.

Clay preparation – While treading with bare feet can produce very well mixed clay batches, the probability is that the moisture content would vary considerably leading to further variations in brick size. Such applications need a proportioning system to maintain consistency batch by batch and a facility to temper the clay over at least 24 hours to permit the moisture content to homogenise throughout the batch.

Brick forming – Although the sandmoulding system is known to the Ghanaian producers, they have not yet acquired the self-releasing mould method which would greatly reduce the requirement of skill in handmoulding. The experiments with a brick press lacked a smooth running procedure for charging the machine and taking away the finished product. Many of the distortions seen in the finished products are likely to have occurred in this initial handling of the green bricks.

Drying – The Ghanaian plants use fixed drying rack systems which puts the permanent buildings to better use than most other African brick industries, which dry bricks singly on the ground. However, drying conditions vary sharply between seasons depending on humidity and wind strengths. For instance, during the Harmattan season in January, the dry winds from the north can dry a brick hard in a day which can cause both cracking and distortion of bricks whereas a few months later the atmosphere is so damp the bricks can take ten times as long to dry. An appropriate technology is needed to adjust the drying environment of the production building so as to mitigate the extremes of drying conditions.

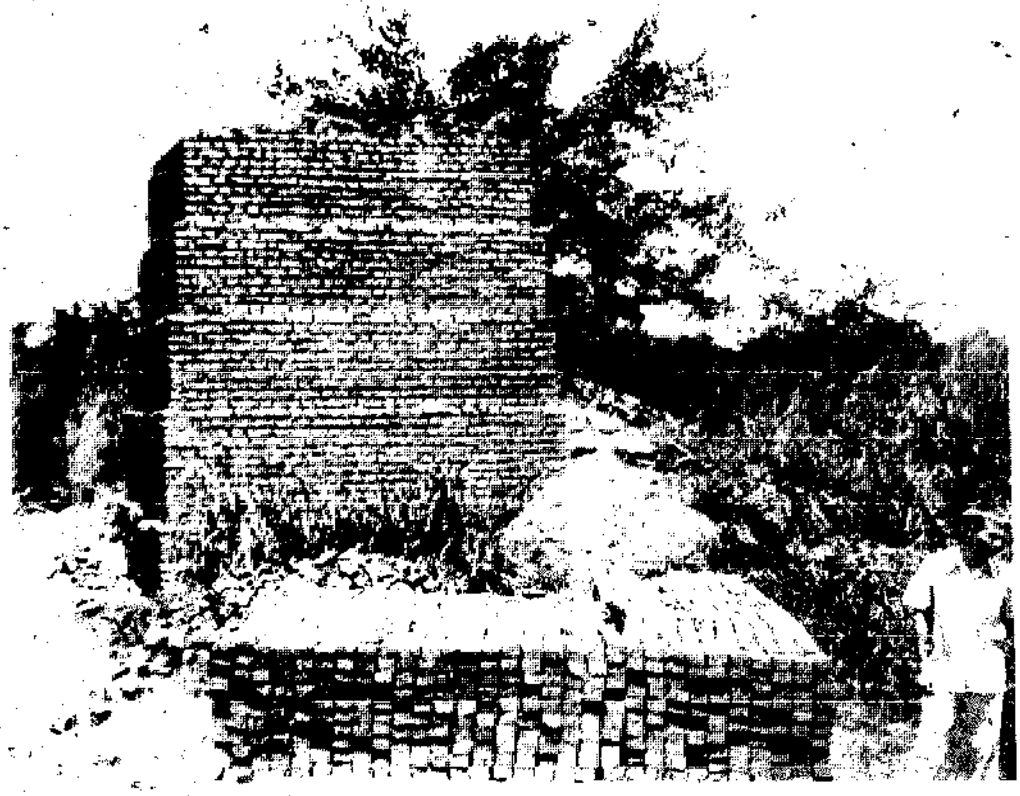
Firing – Although firewood is fairly plentiful in the central and western coastal areas, it still amounts to a significant cost. More efficient kiln grates or a larger proportional use of fuels added to the clay will be of great benefit to the economics of operation.

OTHER AFRICAN STATES

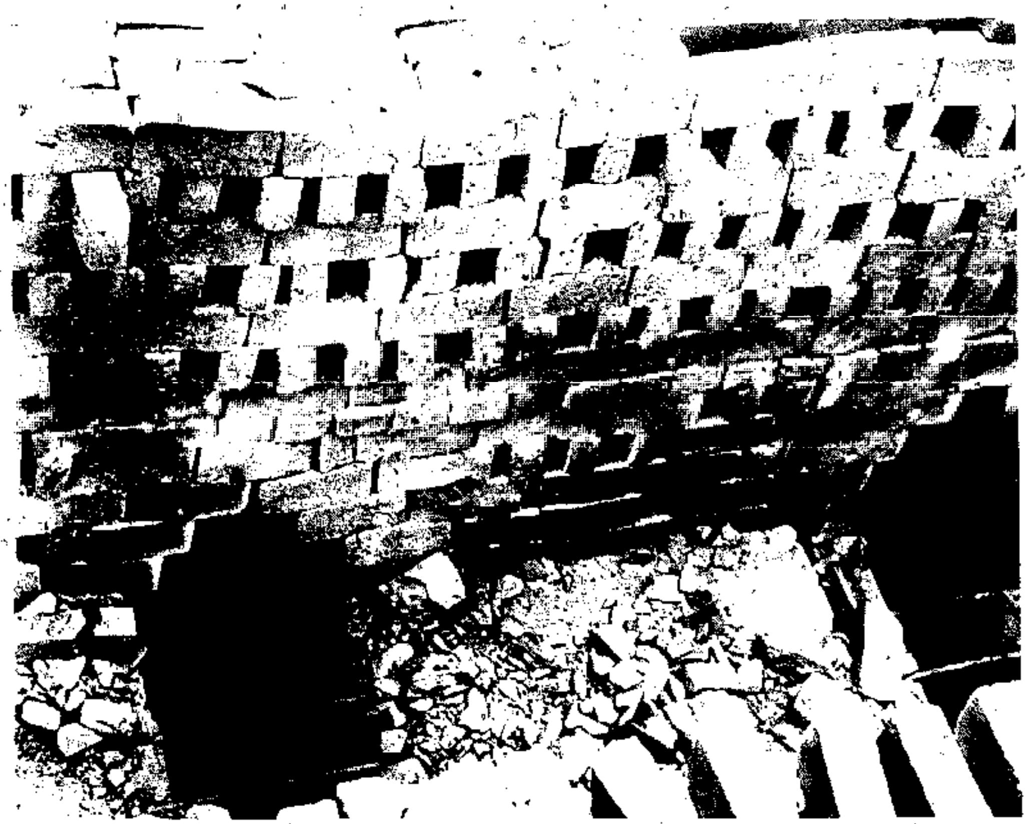
Many of the remaining countries in Africa have concentrated on concrete products for the development of their towns and cities, and others have developed traditional brick industries but with few features that are different from the examples given in greater depth in the previous paragraphs. However, some insight into technical problems can be gained from a brief review of industries which have been visited by the author or for which information is available.

In central Africa, BURUNDI has a strong brickmaking tradition but with almost all of the production grouped in a small low lying area near Lake Tanganyika on the outskirts of Bujumbura. Bricks are also produced intermittently in the hilly area of the north east of the country. The moulding and drying takes place in the open air which confines production to the dry season. Moulding quality is adequate and clamps are of a medium size built along similar lines to those of Malawi. Shortage of firewood for the clamps is a major preoccupation for the brickmakers. While there is no indication that they waste this scarce fuel by firing wet bricks, there is no evidence either that their firing technique is any less wasteful than that of the other industries reviewed. Meanwhile in BOTSWANA the small brickmaking units use the same technology described in Lesotho with both slopmoulded and extruded bricks. By contrast, ETHIOPIA has little traditional brickmaking other than the making of sundried bricks and this too is uncommon. Mechanised brick factories have been constructed in Addis Ababa using high technology processes with heavy electric powered machinery and oil-fired tunnel kilns. The cost of running the latter equipment is

SCOTCH KILNS FOR USED FOR BRICK FIRING IN AFRICA



Scotch kiln used for firing tiles and bricks in the Sudan



Firing channels act as hearth under setting, often producing more consistent results than large 'tunnels' through the brick setting itself causing grave problems since the OPEC cartel quadrupled the price of oil and attempts are being made to overcome the financial drain of firing by trying, for instance to use firewood as a supplementary fuel. Firewood itself is a scarce resource and any development of a rural brickmaking tradition will depend on the availability of a much more efficient system of clamp firing, burning less wood and possibly using various agricultural waste materials as contributory fuels.

Another country without a rural brickmaking tradition but with firm objectives to commence brick production to save import costs is SWAZILAND. The projects have concentrated on large-scale schemes in urban areas. This country had previously obtained all its bricks from South Africa and Mozambique both of which have brick production well established. The Portuguese influence in MOZAMBIQUE has resulted in the predominance of hollow clay block production, these are not normally classified and therefore come out of the scope of this review.

SOUTH AFRICA has a very substantial brickmaking industry in the developed, urban areas of that country and the full range of high technology equipment is in operation for digging and preparing the clay, brickforming, drying and firing. In the last process there are many tunnel kilns and several examples of continuous Hoffman type kilns in operation using coal as the combustion source. The rural areas have many similarities to developing countries in the same continent and many examples of small scale, labour-intensive brickmaking exist. More interesting of them are in the rural areas of Cape Province around Paarl and Worcester where the woodfired clamps reappear together with slopmoulded bricks, and further up the coast in the area to the north of Port Elizabeth, where small-scale brickmakers use brushwood for fuel but undertake the firing in Scotch kilns which have a reduced fuel consumption – in spite of the extra burden of heating up the kiln structure – by virtue of the position of firing grates directly beneath the brick packs. Brick production in some of these rural plants is undertaken by small extruders driven by diesel engines. The extruded bricks are prone to the full range of faults described in Part C with common occurrence of auger laminations, 'dog eared' corners and ragged arrises which preclude the use of these bricks for any other than common infill walls. The lesson to be learned from the quality problems of the South African rural brick industries is that mechanical equipment is difficult to keep in good running order without technically well-qualified attendants, even when the plants concerned are within 30 miles of a major industrial centre like Port Elizabeth which has the full range of engineering facilities and skills available.

The situation in KENYA, the second most industrialised state in Africa south of the Equator, differs from that of South Africa. Brickmaking is absent from most rural areas and only Mombasa and Nairobi appear to have a well established tradition of using bricks. Rural brickfields have played an important part in building the small towns of Kenya in the past and some of the best detailed instructions on the process have come from the former colonial brickfields inspector. However, firewood for burning clamps is now a much scarcer commodity than in earlier times especially because of the heavy demands of the charcoal industry and the emphasis in most of Kenya has swung to production of concrete and sandcrete blocks. The existing factories are predominantly tile works but make some bricks and are equipped with Hoffman type kilns. They are novel in the fact that they consume agricultural waste, rice husks, etc as a fuel, inserted through feed holes in the crown of the kiln in the same way that coal slack is fed in more conventional units. This may provide a technical lead to further development both in Kenya and the embryo brick industry of THE GAMBIA in West Africa. Here the decision has been to go for simpler labour-intensive plants while most 'oil-rich' states of the African continent, ALGERIA, LIBYA and NIGERIA have programmes for developing brick industries but these are all on capital and energy-intensive lines using very conventional equipment as described in Part B.

Heavy duty diesel-powered mixing machine used to mix straw into the clay

Bricks moulded onto the ground in extensive open working and drying area adjacent to kiln

Bricks placed in open setting in deep chamber of continuously firing kiln (fire moves round in a circuit).

Oil drip feed pots placed over the kiln firing zone add supplementary fuel into the hot brick setting underneath

On the West Coast of Africa there is considerable new interest in brickmaking projects in countries which previously had no brickmaking tradition or, like Ghana, where that tradition had died out with the end of the colonial era. Projects in SIERRA LEONE and LIBERIA are larger in scale than the traditional industries tend to be and are incorporating conventional equipment and layouts. Development authorities in CAMEROUN are introducing slopmoulding and wood-fired clamp burning along fairly conventional lines and in NIGER, small projects exist to burn bricks in a locally-designed kiln. An interesting aspect of the Niger development is the addition of millet chaff to the brick clay, a practice which is apparently common with the indigenous brick industry in the Tera area near the main river. Another untypical practice which has antecedents in the traditional British and Netherlands industries, is to gradually build up drying 'hacks' of moulded bricks by adding a fresh row of soft bricks to an existing stack each day.

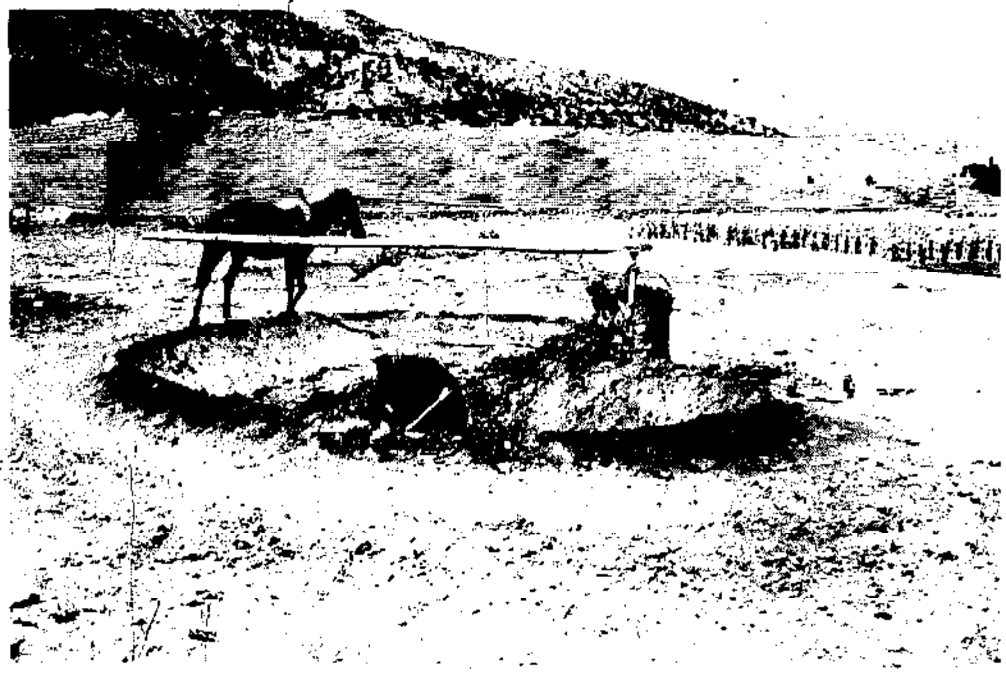
Fired bricks in Niger are regarded as a luxury and most people have to be content to build in mud as do the inhabitants of neighbouring MALI where even in the capital, Bamako, mud construction is the commonest form of building masonry. The essential predominance of mud and mud brick construction throughout the Sahel countries is associated with the virtual absence of indigenous fossil fuels. Such combustible woods and grasses as exist are themselves needed for fertilizer and for furniture and roofing and are too precious to burn brick with. The need for these areas is another system of stabilising or protecting sundried bricks which makes few demands on the scarce resources of combustible vegetable matter.

The last African industry 'visited' before crossing into Asia, is in EGYPT. Here the traditional industry actually does make bricks with straw, one of the only familiar examples of this practice observed in the African continent. The stimulus for this practice comes from the general absence of firewood and the high cost of other carbonaceous materials. Egypt is one of the countries in which mechanised brick production and traditional handmade brickmaking coexist. The dramatic rise in the cost of refined fuels has naturally damaged the economics of mechanised production far more than that of the traditional manufacturers who burn their kilns with crude oil. Competition for agricultural soil since the Aswan High Dam cut off the renewable supply of silt makes the river bank brick industry vulnerable to criticism. New sources of clay have been discovered on the east bank under a limestone shelf and these should now be exploited. In the longer term the best interest of the building industry is to turn again to partially building in mud with new techniques to improve durability.

The position of brickmaking over the African continent is full of contrasting circumstances which call for very different solutions. The predominant problem appears to be how to obtain the desired duration and level of temperature for burning with the minimum consumption of fuel. Second only to this comes the problem of maintaining production levels in spite of sometimes extreme variations in the rate at which the bricks will dry. Raw materials generally need to be dug and mixed more evenly than at present and the proportions of water added better controlled. The handling of materials and dried or fired bricks between processes is frequently one of the most labour-wasting parts of the traditional technologies and much of the work is unnecessarily uncongenial due to lack of suitable tools and equipment.

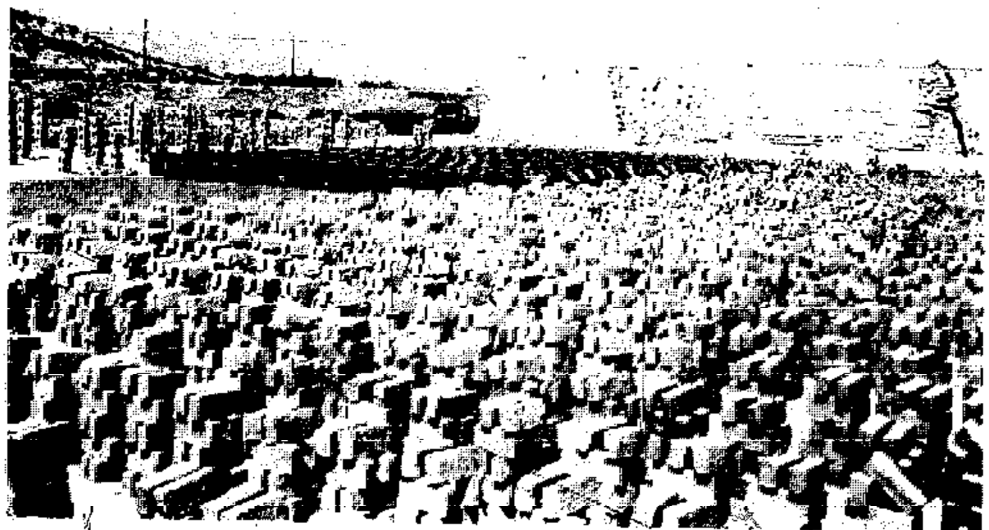
TURKEY

Examples known of Turkish brickmaking cover an equivalent range of capital intensity to two African industries, those of Ghana and South Africa. A factory at Pamukyazi in Torbali District operates a continuous Hoffman kiln of the type used in Accra and in the Cape. This kiln is coal fired, fed conventionally through ports in the chamber crown. The plant as a whole is equipped with covered drying areas in which the products take a surprisingly long period to dry – 20 to 45 days. To form the products, the plant employs extrusion

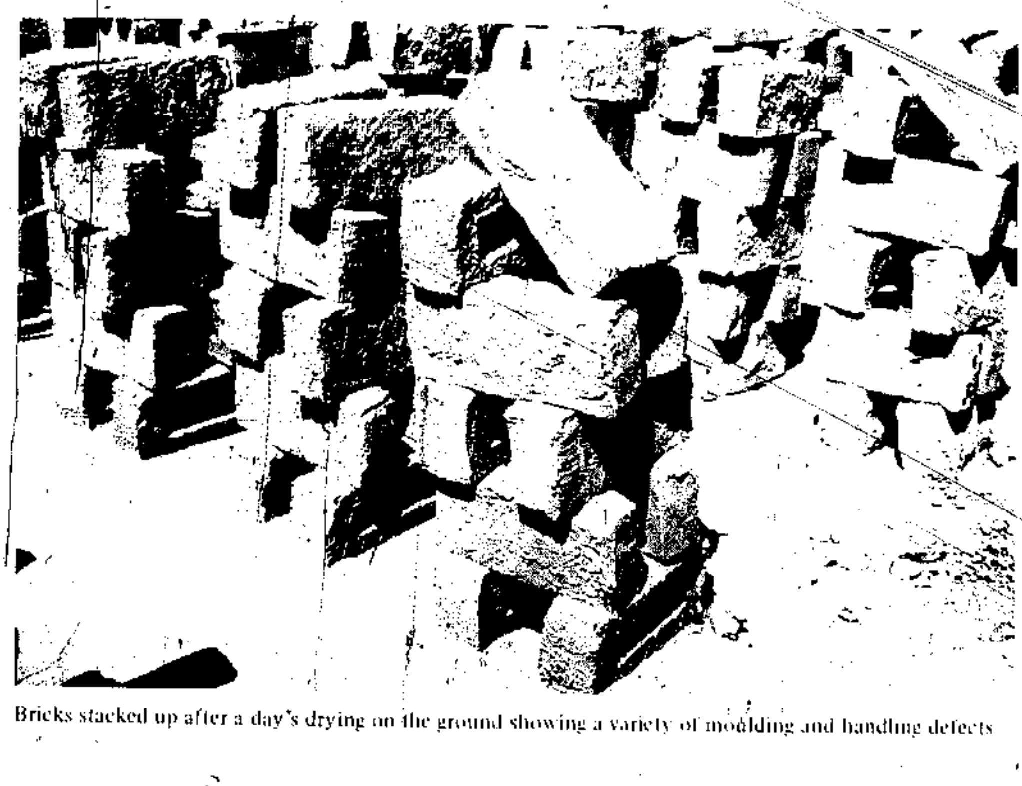


Horse-powered pugmill said to be capable of producing enough clay for 10 000 bricks in a day

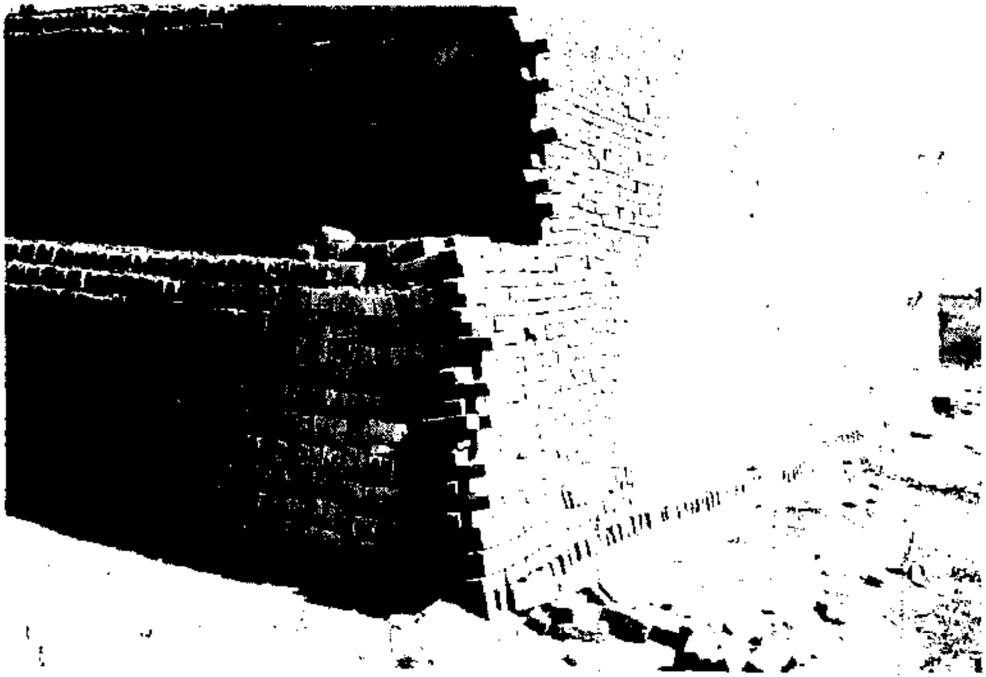
Moulders filling three-compartment moulds at table and setting bricks out on open air drying floor



Large number of bricks set out on uncovered drying ground are very vulnerable to unseasonal rainfall



Bricks stacked up after a day's drying on the ground showing a variety of moulding and handling defects



Extremely high standard of coal fired clamp construction likely to achieve a high efficiency of fuel consumption and consistent burning wirecut equipment which is used to make floor blocks and hollow bricks. Production of solid bricks is left to the traditional industry.

The 12-chamber barrel-arch kiln seems unusually short (the generally accepted 'minimum' size being 16 chambers) and during the hottest part of the year it must be a major problem maintaining the draught and moving the fire to achieve a heat transfer, because the chambers awaiting emptying would be almost too hot for men to enter.

Enterprises of the Pamukyazi type will have taken a major capital investment to set up whereas not far away in Saglik Köyü, brickmaking is carried on with very small resources of equipment which will have cost very little. Six or seven brickfields operate in a small area using basic equipment, most interesting among which is a horse-powered pug mill for mixing alluvial clay with water. One such unit is apparently able to keep three groups of five men supplied with moulding clay for 10 000 bricks in a day. The clay reaches the moulders' table by wheelbarrow having been first shovelled out of the pit below the pug mill. Moulding combines the technology of the slopmoulding flat setting with sand-moulding as the release method. Bricks are carried to the drying floor three at a time and deposited from the mould onto a smooth level ground.

In spite of this fairly well equipped production set-up, the brickmakers still manage to produce a full range of moulding faults with missing corners, wedge shapes, contaminated bottom faces, and setting marks. With what is obviously an 'easy' clay the traditional industry should be capable of making a first class handmade brick with some modifications to their working methods.

Their clamp firing is clearly a far more well regulated process than the brickmoulding and the brickfields contain large accurately constructed clamps which should achieve a good measure of consistent burning at adequate levels of fuel efficiency. This is obviously necessary with Hoffman kiln fired units competing in the same trade.

The main fear for the traditional brickmakers will be unseasonal rainfall, as tens of thousands of bricks on the drying ground could be written off in a few hours if this occurs.

PAKISTAN

Two types of technology operate side by side in Pakistan with at least two mechanised plants already established in urban areas and a substantial 'traditional' industry of small enterprises, working with simple tools and equipment on the outer fringes of large towns. An important feature of this country's industry is the facility of some small brickmakers to produce a first class handmade brick in spite of their lack of sophisticated production equipment.

Clay winning and brick moulding – These better bricks are frequently made by very skilful moulding teams often working in the most difficult conditions in the full heat of the sun, manually mixing their own clay in shallow pits and setting the bricks out to dry on the ground. The moulding technology is substantially similar to that of the Turkish producers described earlier but the constraints of what the market will accept as a good brick may be different, which could account for the existence of some high quality grades. Elsewhere the slopmoulding system is employed and many of these bricks are nearer to the poor standard which prevails over most developing countries' traditional brick industries.

Brickmaking by many of Pakistan's traditional producers is an itinerant process as it is customary only to dig shallow claypits so that the land can be converted back to agricultural use after brickmaking moves away. This feature discourages the establishing of covered work areas which in turn keeps the nature of employment intermittent and uncongenial.

Drying and firing – Lack of cover confines traditional brickmaking to the dry season for the reasons described in earlier sections. Heavy rain also affects the early production stages and the firing process.

The second and probably most significant feature of Pakistan's brick industry is the widespread use of a **continuous** kiln by the traditional industry. The unit used is the Bull's Trench, an open topped version of the barrel arch Hoffman kiln which achieves efficient re-use of kiln heat by drawing the exhaust combustion gases from bricks being fired through to successive batches of bricks awaiting burning. The efficiency is enhanced by the fact that the input cold air is progressively heated up before it reaches the fire by being passed through the bricks which were fired earlier in the cycle and which are now cooling down. This continuous process is made possible by gradually moving the fire round an oval circuit from which the burnt bricks are withdrawn after the fire has passed by leaving a space which is filled with new batches of dry bricks awaiting firing. Draught is achieved by a tall chimney positioned ahead of the fire which pulls the kiln gases from the entry point through the fire and forward through the bricks which are thereby preheated to dull red before any fuel is actually fed into the chamber.

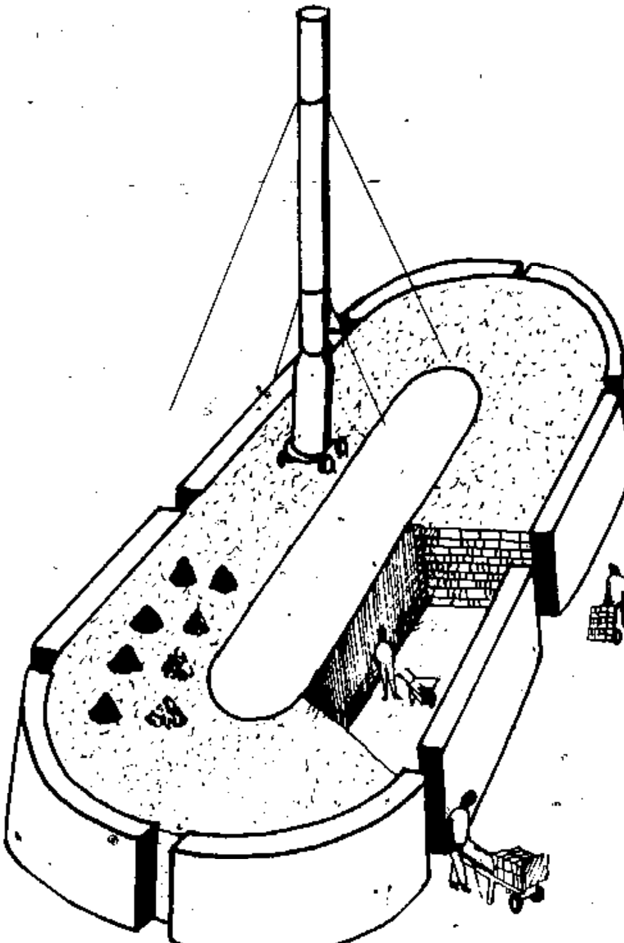
The movable chimney is commonly regarded as a source of difficulty and high maintenance cost due to handling problems on windy days and the corrosive effect on the steel tube of the products of combustion from coal firing. Some producers in the Rawalpindi-Islamabad area have invested in permanent brick chimneys, positioned in the centre 'island' of the kiln. The gases are brought to the base of this chimney by a central flue which is controlled by a system of dampers. Fuel efficiency is far higher than that of intermittent kilns and clamps but producers often use insufficient coal to burn the bricks fully, with maximum temperatures often not exceeding 900^{o}C.

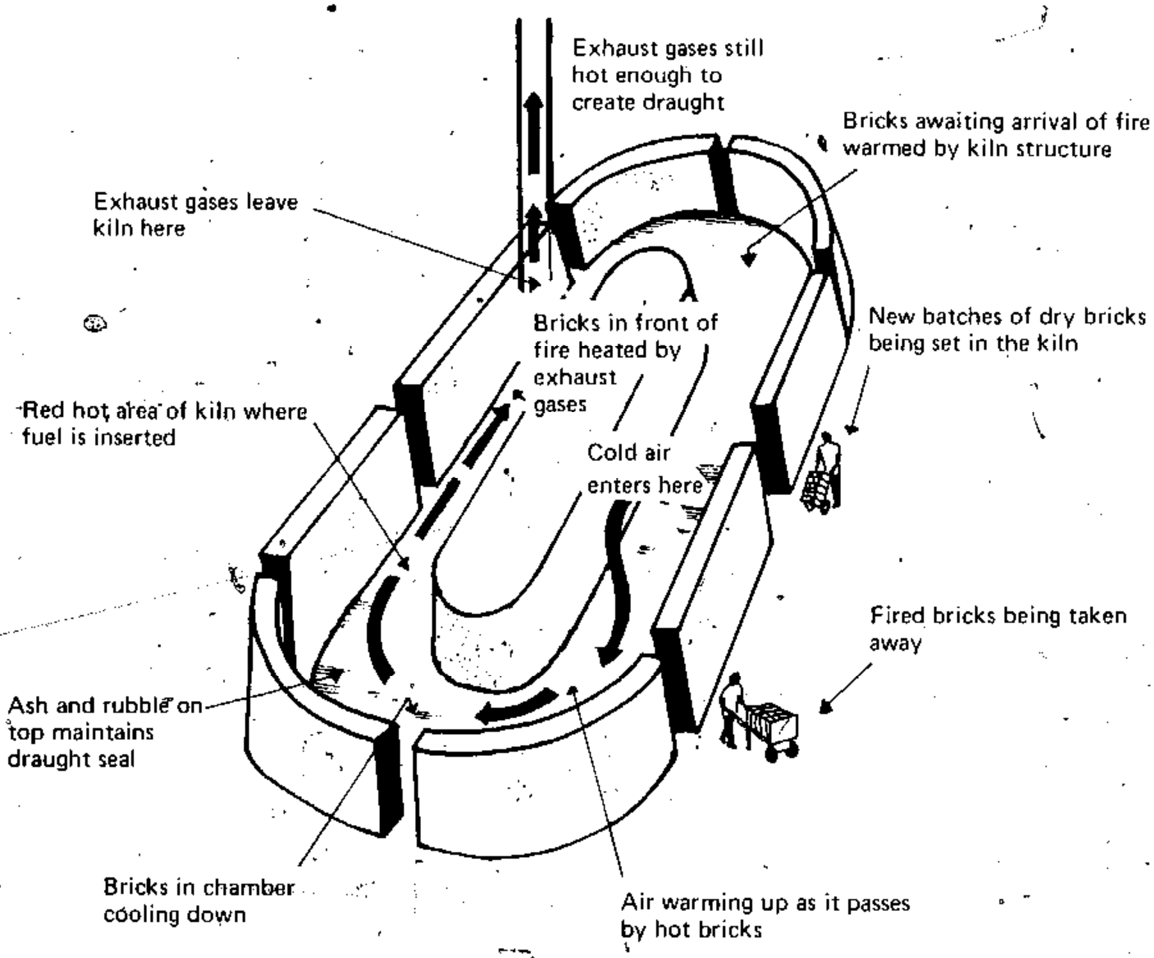
Pakistan is fortunate to have discovered large quantities of natural 'Sui' gas which is now being used to fire bricks in Bull's Trench kilns. As these kilns are necessarily top fired units, they do not always achieve best results with gas firing as this fuel is used at its best through side firing burners near the base of the setting.

One of the main technical problems of the Pakistan brick industry is efflorescence, due to heavy inpregnation of sulphates in the soil in turn caused by water-logging of the ground. The traditional bricks are highly porous and in burning they rarely reach a temperature necessary to neutralise the effects of magnesium sulphate and so as a result efflorescence frequently occurs and can occasionally be severe enough to affect the properties of the brickwork mortar and disrupt plaster coatings. The solution to this may be a local one and involve changing the practice of digging shallow clay pits in favour of deeper quarrying which would effectively diminish the proportion of salts in any given batch of brick clay.

In remoter areas away from convenient supplies of coal of 'Sui' gas, brickmaking has to rely on other fuels. It would be possible to burn bricks with scrub wood in some of the forested mountainous areas of the north but this is not apparently done at present. Similarly, the commonest domestic 'fuel' used for household cooking is cow dung which could presumably be used as a combustible additive to brick clay as is done with camel dung in the Sudan. However, the case is so strong for this material not to be burnt at all but to be used instead as fertilizer, that this proposition should not be considered. If it were possible to

WORKING PRINCIPLE OF THE BULL'S TRENCH CONTINUOUS KILNS USED IN PAKISTAN AND INDIA





collect dung for central processing for methane production and to burn the methane in a brick kiln, then the proposition might make more sense, as the fertilizer would still remain in the sludge. So far no suitable technology for combining these activities has been developed.

INDIA

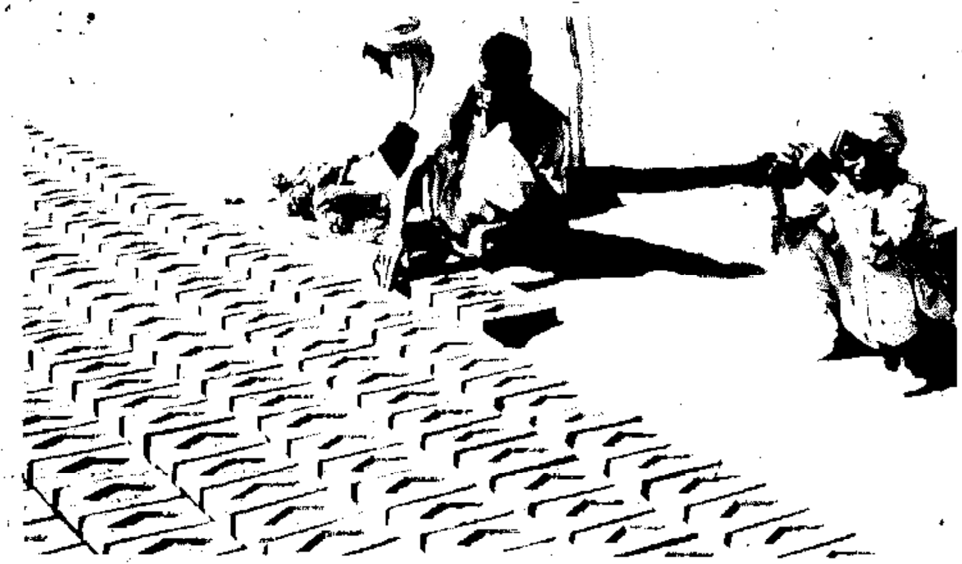
Much of India's brick industry generally fits the description of the process as carried out in Pakistan. The Bull's Trench kiln is in very widespread use although there appears to be many more examples of clamp burning in India and also some instances of wood fired intermittent kilns. Much less of the country consists of irrigated plains and so the industry is more occupied by the need for an all the year round water supply and brickmaking therefore tends to be concentrated near rivers, ponds or reservoirs. Manual pick-and-shovel methods are normally used to dig the soil and many of the smaller producers rely on foot treading to prepare the raw material for brickmaking. It is common practice to leave prepared clay for several days' weathering and at the same time a proportion of the moisture content is allowed to evaporate away to bring the material to the best consistency for moulding. This is a fundamentally sound practice and adoption of it would benefit brickmakers in many other countries.

In some brickfields the same type of pug mill which was described in the section on Turkey appears also in India but instead of being powered by a horse it is normal to use two bullocks controlled by an attendant. Indian brickmakers in many areas have to contend with a more variable climate than that of Turkey or Pakistan and as a result it is far more common to encounter a proper working building constructed alongside the kiln where bricks are moulded and set out to dry. This is facilitated by the availability of a cheap locally made roofing material, the Mangalore tile.

India has many examples of mechanised brick production using the extruded wirecut process but the price of these bricks necessitated by the cost of owning and operating the machinery is generally more than twice that of a handmade brick. Similarly, India has instances of calcium silicate brickmaking, including one unit in Kerala, which use high pressure autoclaves to steam cure bricks made from sand and lime. Again the price of these is more than twice that of a handmade brick – the complete reversal of the situation in Britain where a handmade brick fetches three times the price of a sand-lime brick. Unlike handmade bricks from many other developing countries, the moulding ability of Indian brickmakers can be extremely precise and so the complaints by customers are more likely to concern the firing rather than the shape and accuracy of the bricks.

Generally the country is well equipped to evolve its own technologies for improving brickmaking, having central trade and research organisations in New Delhi and Roorkee, UP and having the necessary industrial base to design and fabricate special equipment. However, much of traditional brickmaking is still laborious and unpleasant due to poor practices in manual operation and interprocess handling. Therefore any new low cost equipment designed to lessen the laboriousness of moulding bricks and moving them between the processes of making, drying and firing will be of considerable benefit.

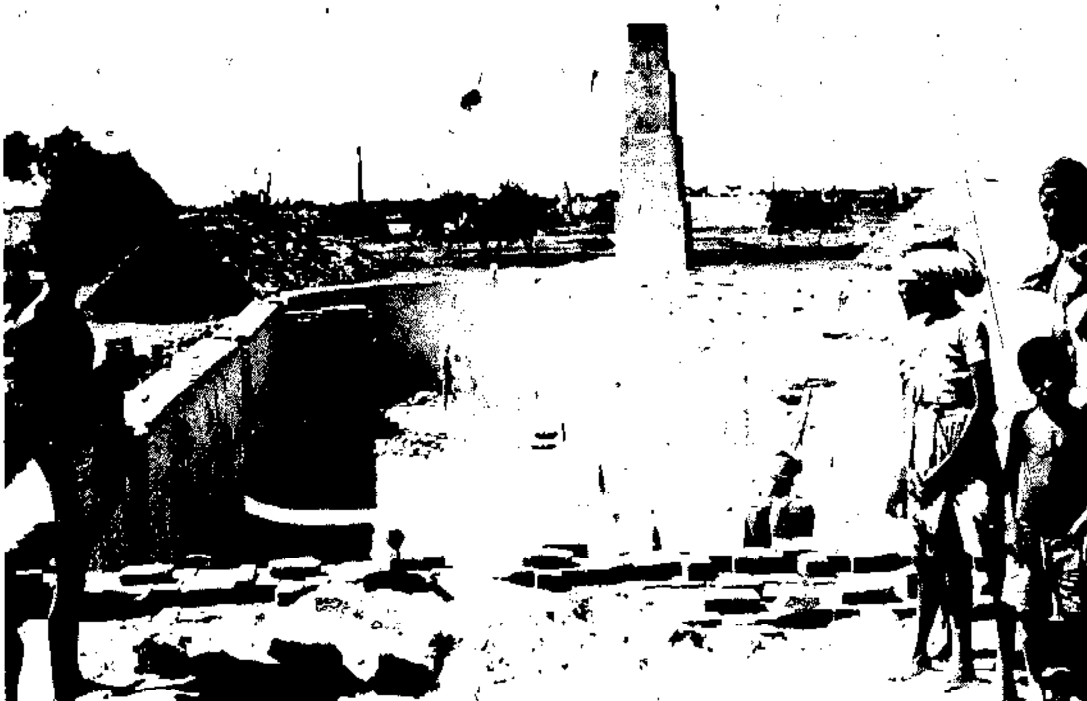
The Bull's Trench kiln is the innovation with most promising development potential of all the equipment encountered in India and Pakistan. At present the units need to be relatively large containing a quarter of a million bricks and firing 60 000 or more bricks a week to be able to function properly. They also produce a variable fired product due to difficulty of control and fluctuating performance with changes in wind and humidity. Moreover, they provide a dirty and dusty working environment for the kiln workers. Development work to establish the same benefit of continuous firing but of a smaller output and with better control and conditions would not only assist the Indian industry but also would make a promising technology to transfer to other locations, particularly if the kiln could be made to function efficiently with a variety of other fuels as well as coal.



Precisely produced sandmoulded bricks achieved in spite of incongenial working position of brick moulders

Kiln burners feeding coal through firing ports of Bull's Trench continuous kiln

General view of plant showing movable metal chimney alongside permanent brick chimney. Note covered production building on right side of picture



Vacant chambers of Bull's Trench kiln taken from the point where the dry bricks are being set, looking towards the corner where the fired bricks are being drawn.

Drawer loads newly fired bricks onto barrow for wheeling out to the stockyard. The powder on top of the bricks is mainly ash from the coal firing

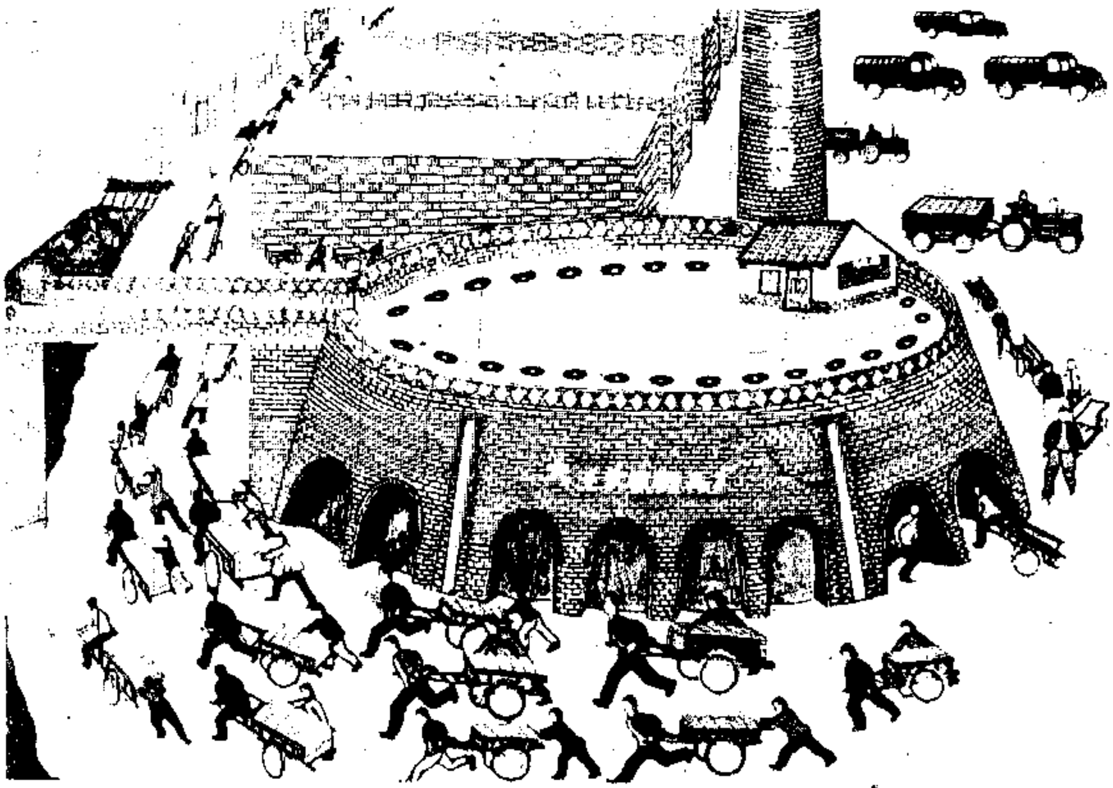
INDONESIA

One of the parts of the Indonesian archipelago where brickmaking is an established indigenous industry is Bali, where families of rice farmers frequently undertake brick production during slack times of the year between rice crops. Production takes place close to public roads to allow access for vehicles bringing firewood and taking away finished bricks. The methods employed while similar to those of Irian Jaya and other parts of the country are far from typical of other developing world applications and are summarised as follows:

Clay winning and brick moulding – The Indonesian brickmakers regard their material in the ground as ready prepared clay and deliberately keep the shallow clay pits filled with water so the soil stays moist and ready for moulding. With clays which have a potential for cracking, it is normal to add chopped rice stalks or 'lalang' (a sharp-leafed hill grass) to the clay which involves a quick mixing process with hand tools carried out in the pit. Bricks are moulded in fives using a mould which is operated by two people and consists of a straight through frame. The bricks are moulded directly onto the ground and the mould left in position for some time so that the bricks begin the drying process while actually still in the mould. Then when the bricks begin to shrink, they detach themselves from the sides of the mould and the operators lift this clear and set it down in the next position. With several mould sets the brickmakers can make around 500 bricks in a day using this method. The other brickmakers who leave the mould on the ground are those of Lesotho but in their case the moulds become free so quickly that only two sets need to be employed.

Drying and firing – The bricks continue to dry, lying flat on the ground until hard enough to handle when they are stood on edge in a low stack to complete the drying process. Surprisingly little distortion takes place during the drying process which must be by virtue of the clay and only minor moulding faults such as turned up corners occur. The kilns are small scale 'Scotch' type units with open trench fireboxes able to burn around 4 000 bricks at a time. The wood-firing process is extremely short, lasting for only 24 hours and the bricks tend to be underburnt, signalled by the fact that the brickmakers cover the finished products with grass to avoid their being damaged by heavy rain.

With the type of family brickmaking described here, it is quite appropriate for the process to be an intermittent one as the people concerned are not depending on brick production for their livelihood but instead as a means to gain a little extra cash income. There are no doubt ways of improving working arrangements which would enable the same group of people to produce more bricks in the same time or the same number of bricks in less time but on the whole the occupation appears to be quite a congenial one in the climate of this area and not meriting a great deal of modification. In areas where the demand for brick outstrips the capacity of this highly informal industry to supply and there is a long term need to produce larger quantities more efficiently, a whole range of more productive methods should be introduced, including sandmoulding, covered drying, wheeled trucks for brick and clay movement and large, fuel-efficient clamps.



Chinese artist's illustration of 'Tawang Commune Brick Factory' in Shensi province

OTHER ASIAN STATES

In the remainder of the continent, brickmaking varies sharply from location to location. In IRAN the methods employed are similar to those of Turkey and India with both sand and slop moulding in use at the forming stage and conventional Hoffman and open top (Bull's Trench) Hoffman kilns employed to fire the bricks as well as some coal fired clamps. A major new investment is now also taking place involving construction of a large factory with transverse-arch Hoffman kilns and mechanically pressed brick production. The states of MALAYSIA mainly build in non-brick materials but that brick production which does take place is mechanised with extruded wirecut bricks fired in tunnel kilns. In PAPUA NEW GUINEA there is little or no indigenous brickmaking of the type described in Bali, but bricks are made by some government bodies such as the Prison Service at Bomana and elsewhere. The technology here is based on a locally made hand operated brick machine and handmade bricks as such are not produced. Slopmoulded brick production has long been an indigenous skill in CHINA and instances of this can be seen in the New Territories of HONG KONG. No doubt there has been considerable development of labour intensive brickmaking skills in communist China but no recent published information is available for this review apart from an interesting commune painting which appeared in a recent exhibition of workers' art. From this can be gleaned that the brickmakers are operating a multi-chamber continuous kiln and move bricks about in a variety of hand trucks, usually at a run!

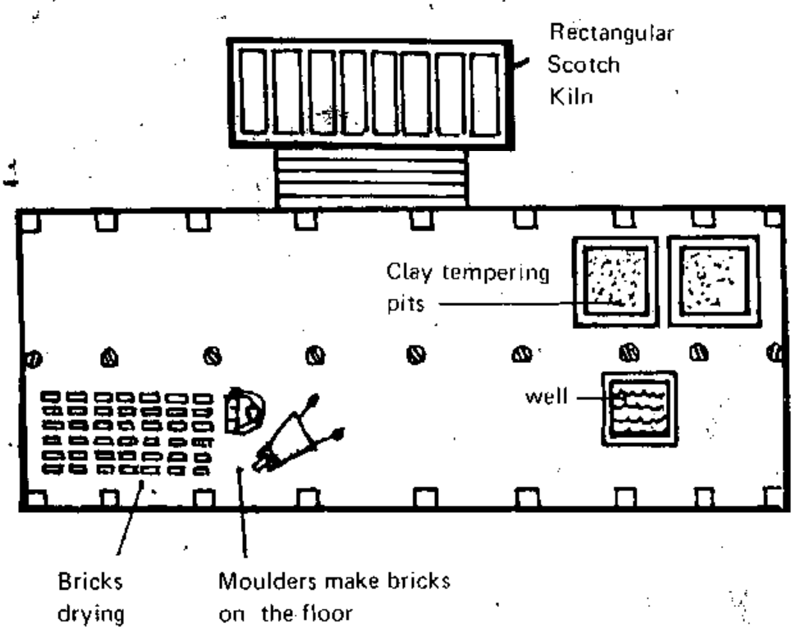
HONDURAS

Most of the Third World traditional brickmakers tend to congregate in special areas such as river banks adjacent to larger population centres. Accordingly they rely on the city as their market and the people in smaller centres in rural areas generally do without permanent materials which are regarded as financially out of their reach. A notable exception to their pattern exists in Central America where it is commonplace for small towns and even villages to use locally made clay bricks and hand moulded tiles in the fabric of the humblest dwelling. The technology is most well entrenched in the countries such as Guatemala and Honduras with a strong Spanish tradition. Unlike much of Mexico to the north the abundant forest and high rainfall provide both the opportunity and the need to produce permanent materials to increase the durability of structures.

The traditional brick and tile industry in Honduras is extremely widely dispersed and, unlike most spontaneously evolved activities of this kind, has invested significant resources to assist production. Virtually all the bricks are fired in Scotch kilns or at least on permanent checkerwork fire grates with side walls. Many examples of production buildings have been constructed specifically to house brick and tile manufacturing activities. This contrasts with the broad commentary on most of the world's traditional brickmakers who are under-capitalised to the extent of not even using wheeled trucks to move materials about.

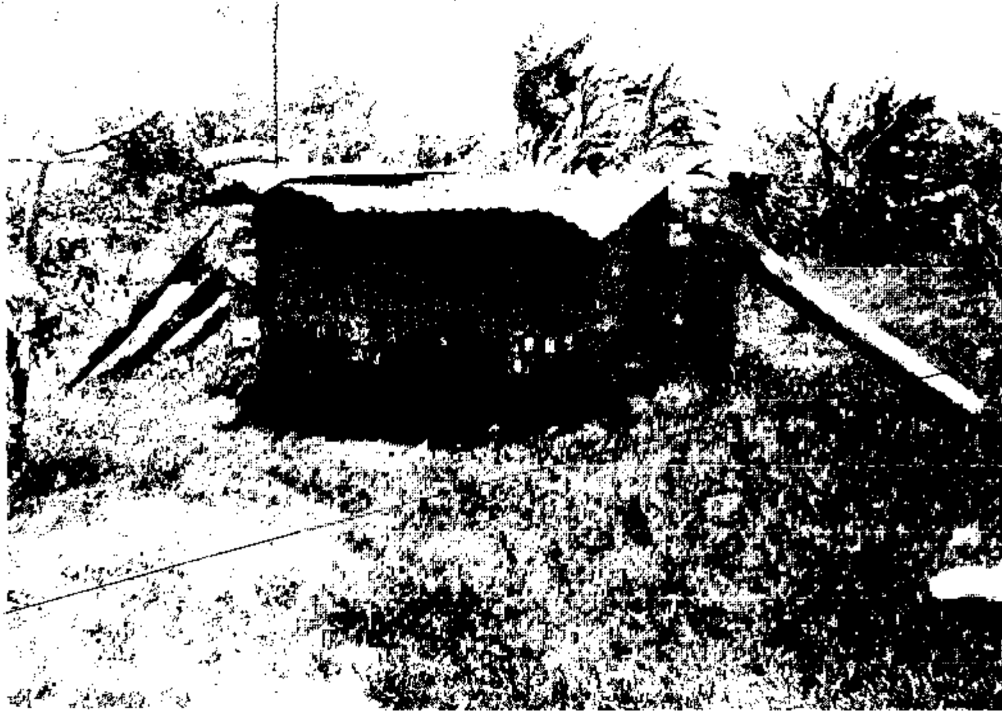
Another feature of some of the traditional plants in Honduras is the existence of properly constructed pits for tempering the clay prior to moulding. In other traditional industries it is more normal to mix the clay in the quarry often on the same day that the material is used for brickmaking. Apart from the difficulty of measuring quantities and therefore controlling moisture content, the practice of adding water in the quarry unnecessarily increases the weight of material to be brought to the plant, by 20–30 per cent. This is an important inefficiency, especially if water is available at the moulding location itself, from a well or by mains connection. The Honduran practice of preparing clay in tempering pits within the brick production area is both more efficient and leads to better quality control. More than usual care is taken by some Honduran traditional brickmakers to make products which are as accurately formed as possible. However, instead of modifying the moulding method from slop moulding so as to produce a better shaped brick in the first place, they usually fettle the rough corners and edges after the bricks have dried.

Well organised village plant showing permanent tiled roof, level drying floor and clay tempering pits in the foreground



Brickworks layout

After drying the bricks are fettled to improve shape



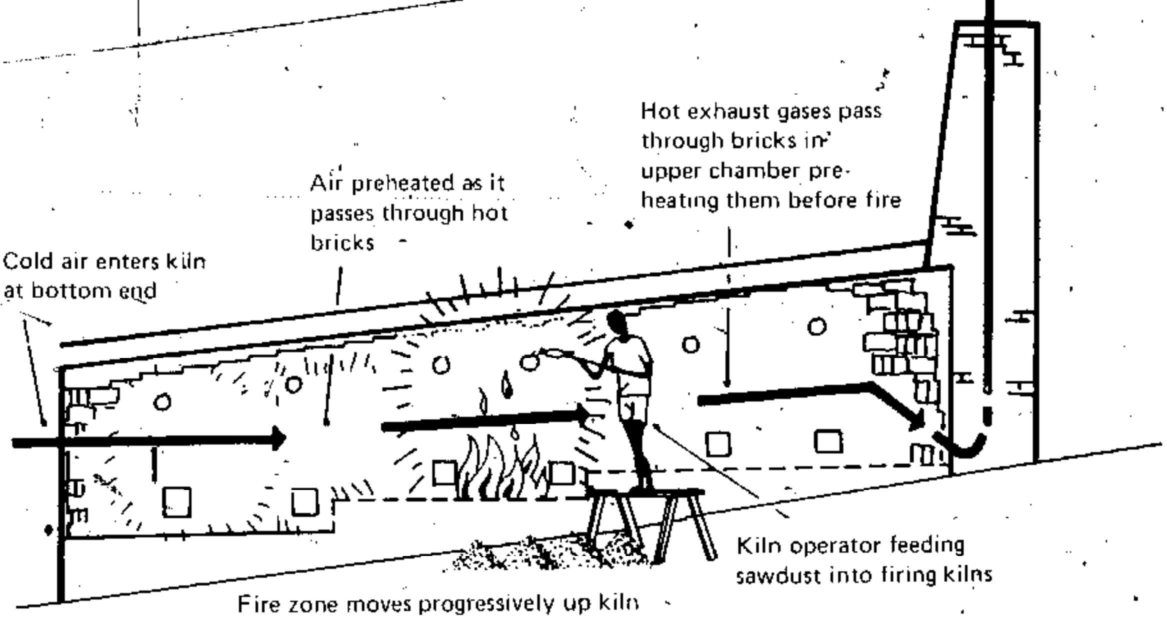
Even on the smallest scale of operation permanent fire grate is used as base for burning load of bricks

HONDURAS SEMI-MECHANISED MEDIUM SCALE BRICK PLANTS

Clay receipt area and drying sheds

Sloping kiln

Kiln burner feeding sawdust into Hoffman kiln



The principal fuel used for burning the bricks is firewood, a quite plentiful and renewable resource in a country which is well forested as a whole. Nevertheless, in areas of high population density such as around Tegucigalpa the capital, firewood is becoming increasingly expensive to obtain and alternatives are being explored. Most significant is the plant of a medium-scale brickmaker who has begun to burn sawdust as his main fuel. The development of sawdust firing has been greatly aided by the introduction of facilities for continuous firing in one continuous and several semi-continuous kilns. The continuous kiln is a standard Hoffman design of European origin but the semi-continuous units are derived from practice elsewhere — probably Japan where similar units are known to have been used. The design consists of a straight barrel arch chamber constructed on sloping land so that the kiln floor runs uphill in a series of steps. The semi-continuous firing is achieved by beginning the burn in the lowest chamber, then progressively drawing the fire gradually 'uphill' by injecting new fuel into the chamber just ahead of the fire. Once a fire is burning in the first chamber of a semi-continuous kiln the smoke passes through the cold bricks in front of the fire and so preheats them saving the fuel which would have been needed for this. Subsequently, after the fire has passed further up the kiln, a second form of heat exchange begins to take effect. The air needed for combustion of the fuel enters the kiln at the bottom end and before it reaches the fire it passes through the spaces between the bricks in the lowest chamber which were previously being fuelled. These bricks still being red hot, preheat the air before it reaches the fire — again causing a significant saving in the amount of fuel needed. The heat-exchange process continues until the fire reaches the top end of the kiln and is allowed to go out.

The combination of preheated kiln, air and preheated bricks makes it all the more possible to use for fuel materials such as sawdust which do not burn readily when injected into a cold kiln chamber, but ignite immediately when in contact with a red hot atmosphere. Sawdust is plentiful in countries such as Honduras with a timber extraction and sawmilling industry for domestic and export markets.

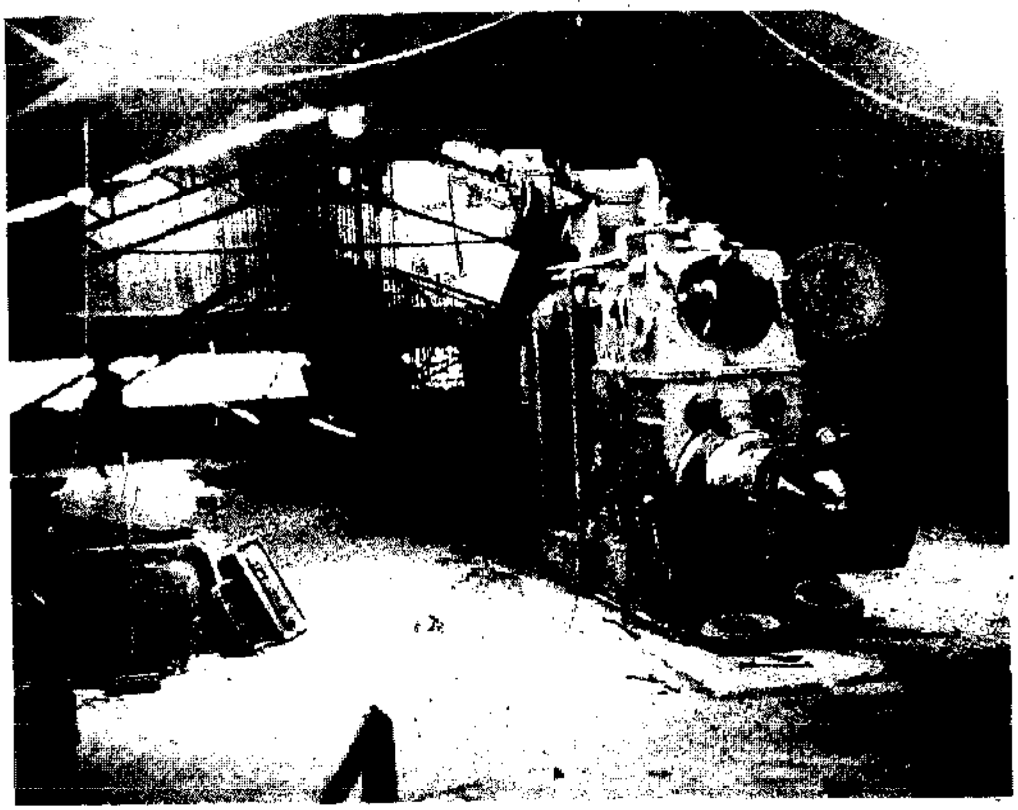
Some investment has taken place in mechanised forms of brick production using imported Spanish clay preparation and extrusion plants. The products sell readily because of their regularity of form and 'machine produced' appearance but the price is up to three times that of the traditional handmade brick, reflecting the high cost of powering and maintaining the mechanised production lines. It is significant that the machine made bricks in Honduras are priced at much the same level as bricks made in Europe, whereas the traditional handmade products are far cheaper than anything made in industrialised countries. In the rural areas of Honduras, unemployment is rife and labour cheap. Without the brick and tile industry the situation would be much worse and more of the population would have moved to the already overcrowded cities.

THE CARIBBEAN

There is little evidence of indigenous traditional brickmaking on the small islands of the Caribbean and predominant construction systems use mainly timber or concrete. One instance where clay brickmaking has been established, but not in a 'traditional' form, is in the north west corner of BARBADOS. A labour-intensive plant operated for several years on the island and on the basis of its success investment was made in a more mechanised unit. This is clearly being run with more than usual technical competence, as the products are well formed and consistently fired. Nevertheless, as with most mechanised units located remotely from machinery suppliers, the Barbados factory has from time to time incurred long stoppages due to breakdown of crucial components which require replacement by imported spare parts. The high fixed cost levels of the operation and the nature of the firing

Railway used to bring clay from quarry to plant

Manually operated truck for moving products from extruder to drying chamber



Extrusion plant temporarily out of commission due to delay in arrival of spare parts (with oil) have been factors forcing up the prices charged for the products. Expensive bricks inhibit sales at all times but the problem of dealing with large volumes of unsold brick stocks becomes exacerbated in the harvesting season when the building trade slows down. Measures taken to deal with the sales problems have included product development work generating an attractive range of decorative screen bricks and tiles and the development of export markets, supplying products to neighbouring islands which have no brickworks.

OTHER CENTRAL AND SOUTH AMERICAN STATES

Brickmaking in this part of the developing world is not so well documented as that of Africa and Asia, and for cultural and geographical reasons the industry is much less widespread. The strong Spanish and Portuguse influence over most of the area has resulted in a high proportion of those ceramic building materials that are produced being mechanically-extruded hollow clay blocks. Solid masonry tends to be either concrete or adobe – much of the adobe brick or blockmaking using similar slopmoulding techniques to those employed over much of Africa. In the densely-forested areas, buildings are largely constructed out of timber. However, some exceptions to this pattern are known and there are probably many more for which documentation is not accessible at present.

The Government of GUYANA had concluded that many of the wooden buildings common in poorer areas of the country were harbouring disease-carrying pests and so decided to encourage the use of bricks for domestic construction. Help was enlisted from the American brick industry to second staff to help start brickmaking projects. The programme is understood to have encountered some marketing difficulties from builders reluctant to use bricks instead of concrete blocks. Meanwhile further along the coast in SURINAM, one factory has been constructed and put into operation with a Netherlands designed continuous chamber kiln. In Lima, PERU, common brick production is undertaken on a much more spontaneous basis. Here enterprises exist which are novel from a commercial point of view and might provide a lead by which other developing countries' plants could be organised. The system is for a kiln owner to act as a nucleus to a series of small brickmaking concerns. These work groups produce slopmoulded bricks on the conventional open box pattern and then sell their production to the kiln owner. He then organises the firing, using locally mined coal and thus adding value to the bricks, and resells them on the commercial market at a profit. From a technical viewpoint, Lima is an ideal brickmaking centre with virtually no rain but plenty of water (brought from the mountains beyond the dry coastal plain).

MEXICO is another Latin American country with an established handmade brick tradition. The tendency of the small family plants to underfire their products caused 'mexican brick' to be a term indicative of a soft common brick. The American influence in the area has contributed to the successful introduction of high technology plants particularly as the lower labour costs in Mexico have made it a worthwhile business exporting extruded wirecut, tunnel kiln fired bricks to the United States. In such circumstances heavily mechanised production becomes worthwhile and overshadows the traditional industry, although slopmoulded production of adobe bricks, typical of practice all over Latin America, continues in the rural areas. For a different reason, the prosperity brought about by oil, VENEZUELA has also opted for mechanised production of ceramic products. These are mainly hollow clay blocks but some bricks are also produced in small factories. The climate for brickmakers was for a long time ideal, with generous Government grants to assist them to purchase capital equipment, and butane gas for firing literally given away by the oil companies at a time when the only other option was to flare this fuel off at the refinery. The difficulty was that the main markets were in the north around Caracas in a sandy, rocky area, while the clay deposits lay to the south west around Barquisimeto and Valencia. This situation has not favoured the establishment of an indigenous or traditional brickmaking industry but has left the activity to businesses with the facilities to organise installation of mechanical equipment, intermittent and tunnel kilns and the means to transport bricks to the markets in the north. In the meantime, the small indigenous technology of slopmoulded adobe brick production in rural areas has seriously contracted. Much of the brickmaking technology employed in Venezuela is unashamedly energy-intensive with small ceramic producing firms possessing 5 000 litre tanks of lpg, which would cost a fortune to install and repeatedly fill even in Europe let alone in the poorer developing countries. Products are burned in highly inefficient rectangular intermittent kilns with no provision for insulation or waste heat recirculation. The changing situation of energy costs with increasing facilities available to trans-ship propane and butane to overseas customers could potentially ruin brick producers of this type in oil-rich developing countries. Having committed themselves to plants designed as if energy costs did not matter, they could now find themselves increasingly having to pay a more economic cost for these fuels in world terms.

Such a situation might, in the end, lead to development of a more frugal indigenous brick industry, more like those described in preceding paragraphs.

PART E. PRIORITIES FOR RESEARCH AND DEVELOPMENT

General conclusions

The exercise of describing and assessing the main technical problems of traditional brick industries in a great variety of developing countries has revealed several repeating technical problems which nobody has completely solved. Individual remedies have been found which suit particular circumstances in one or other locations, but few of these are in a form to suit immediate application elsewhere.

Other than the total lack of brick clay, fuel or water there appear to be no situations in developing countries where absence of a suitable processing technology has held up the development of brickmaking altogether. Where people have felt a need to produce a permanent building masonry component they have usually found a way of making bricks, from heavily forested areas to semi-desert, using fuels ranging from conventional fossil fuels and firewood to waste vegetable and animal matter.

The prevailing need therefore appears not so much to create technologies which would enable people to make bricks who were previously unable to do so, but more to help people make better bricks, more efficiently, less impeded by climatic changes and in more congenial conditions. These four attributes are important for the following reasons:

Better bricks will increase the range of applications for which they can be used eg loadbearing brickwork in substitution for steel or reinforced concrete frame construction of multi-storey buildings. They will speed the building process and reduce the cost of bricklaying by reducing the amount of work needed to adjust for inaccuracies of brick size and shape. If the dimensions are more reliable, builders will be able to reduce the thickness of the mortar joint between the bricks which will in turn reduce the cement requirement with conventional bricklaying, and increase the possibility of using mortars which exclude cement altogether in certain applications.

More efficiency in the use of production factors will improve the economies of brickmaking and enable those in the industry to make a better living while consuming less resources. This is particularly important in the question of fuel if this is obtained in a scarce or non-renewable form.

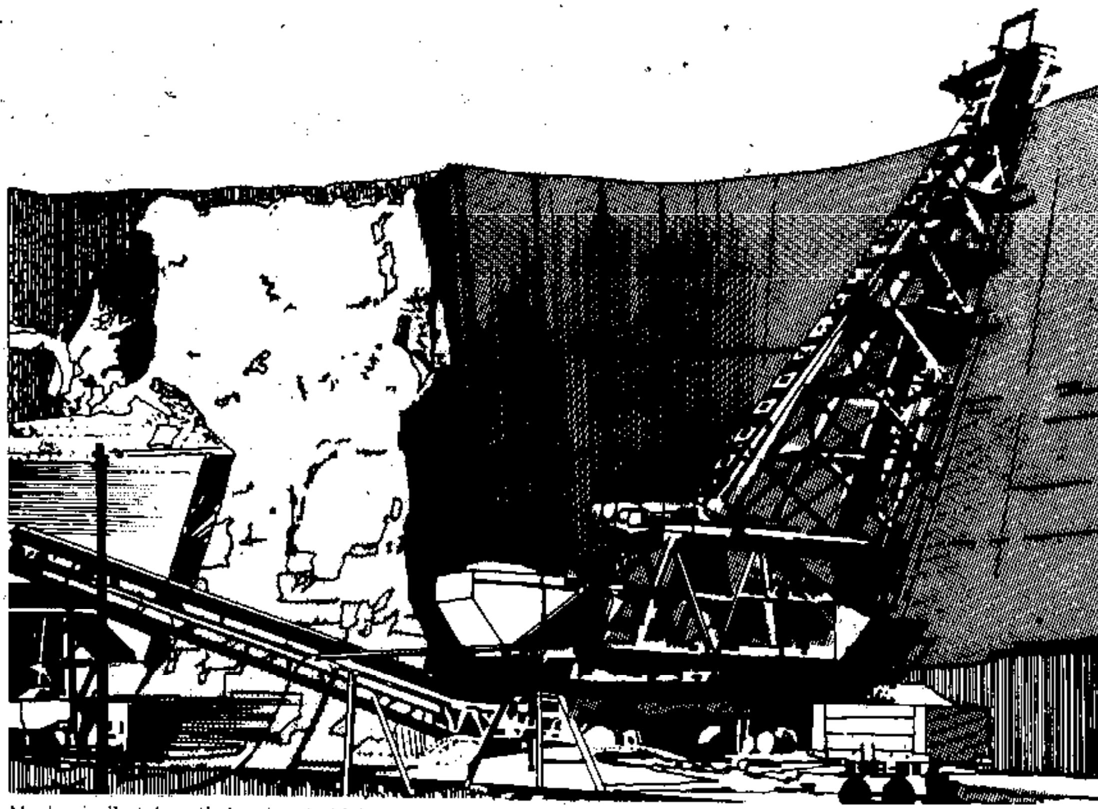
The wet/dry seasonal cycle in most developing countries is very disruptive to brick production even where covered working areas have been constructed. Higher humidity impedes the essential drying stage in the process and excessively low humidity causes losses by cracking the bricks, while rain destroys unfired bricks left out in the open.

Improved working environment and reduced tedium in the production processes of traditional brickmaking will compensate for one of the major attractions of high technology brickmaking which normally is undertaken under cover and substitutes capital and energy-intensive machinery for manual tasks.

Any major advances in these four fields will also have an effect on the economic viability of labour-intensive brickmaking and thereby will influence the spread of the technology to those marginal areas where previously the setting up of an industry was not quite feasible as a proposition.

Improvements to clay winning and preparation

Examples from the description of brick industries of several of the countries reviewed, has identified the need for a method of digging the soil which ensures that an even proportion is taken from all the different layers. This is so that each batch of raw materials reaching the



Mechanically 'planed' clay face in high technology plant produces very accurately proportioned raw material input

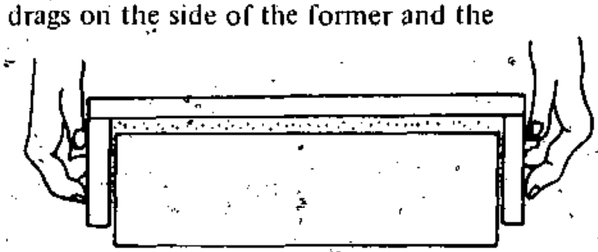
Roughly hand dug clay face likely to produce variable mixing of top and bottom clay production stage has similar moulding, drying and firing properties in order to produce a consistent product. In highly mechanised brickworks these consistent proportions are obtained with the use of shale-planers, multi-bucket excavators or, a little less effectively, by dragline. What is needed is a hand tool or simple mechanical device which will mimic the actions of these heavy machines and, ideally, bring the dug material up to ground level as well.

In many locations the work of obtaining a continual supply of water with which to mix the clay amounts to a major task with a lot of tedium where people have to carry heavy cans from a distant source. Where motor vehicles have to be used for this purpose they add significantly to the cost and increase the reliance on a facility which is not necessarily reliable. A technology to obtain ground water using a hand-powered or wind-powered pumping system from a borehole or well would be a great benefit to many brickmaking ventures as would a simply constructed facility to store this water and catch any convenient rain that falls. During the wet season the same equipment used to obtain water at other times might be adapted to the task of pumping water away from the clay pit when flooding is a cause of production hold-ups.

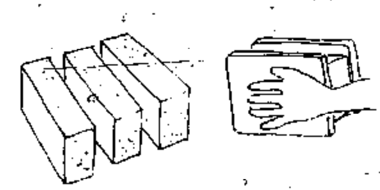
The need to reduce the material lump size in the preparation process is generally performed by mechanical mixers, by treading with bare feet and by tempering (leaving the clay to soak for 24 hours or so). Full mechanisation is likely to stay beyond the reach of many brick industries for a long time to come but the puddling work using bare feet is a tedious task for which it would be helpful to obtain a substitute. The hammer hoe hand tool of the Malawi brickmakers goes part of the way to solving this problem but there are no doubt many materials which will not be as compliant as the local clay with which this tool is now used. One possible avenue of research and development could be to combine the dry grinding process used by many mechanised brick plants with the tempering method, ie to develop a system of pounding clay into a small particle size then leaving it to temper with water added in a suitable storage pit.

Improvements to brickmoulding methods

Developments are well in hand to enable unskilled workers to produce an accurately shaped brick using a sand-lubricated, self-releasing mould. This may turn out to be a widely acceptable solution where sand is readily available in the area of the main clay deposit. This is not universally the case however, and it is probable that many brick industries will consider they have no option but to continue the practice of slopmoulding using only water for the mould-release. A moulding system is therefore needed which will enable these industries to produce better bricks without need to use significant amounts of any material other than water and the brick clay itself. The key to obtaining a well shaped brick with current technology is the lubricating layer or film of material separating the clay from the sides of the mould or extruder die. Without this the clay sticks and drags on the side of the former and the brick becomes distorted.



With sandmoulding the sand on the surface of the brick acts as a lubricant enabling the brick to drop clear without distortion.



This means that the clay can be handled fairly dry and if set down on a pallet as shown in the diagram, the bricks can be taken to the drying floor in groups by truck, and can be turned and stood on edge to dry.

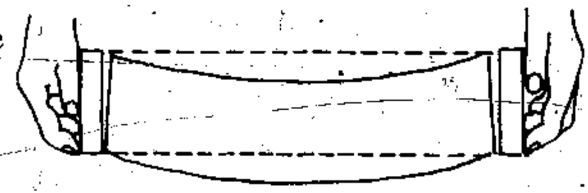
In most traditional brick operations only water is used and is much less effective than sand as a lubricant and only works if the clay is extremely wet and soft. If made any drier the brick absorbs the water film before it can be released from the mould and sticks. If the

BETTER MOULDING SYSTEMS PERMITTING IMPRINT OF NAME IDENTIFICATION ON BRICKS

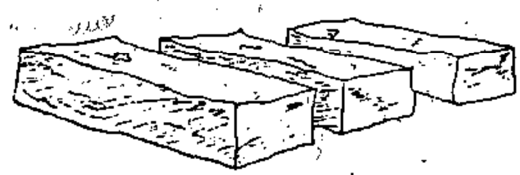
Sandmoulded bricks made in self-releasing moulds. Further development is now needed to obtain equivalent standard with slopmoulding system for locations where sand in not available

Sandmoulded bricks of regular shape and with trade-mark, made in self-releasing moulds by newly trained operators moulder's clay clot is coated with a different liquid, such as oil, before throwing into the mould, when mixed back into the clay any oil left on the offcut will tend to cause laminations in subsequent bricks. This also happens with sand.

With slopmoulding the clay releases itself from the mould by bending in the centre which pulls the ends of the brick away from the surface of the mould. This is then lifted away leaving the brick in position on the floor.



The clay is always made very wet which means that it is too soft to be handled subsequently and must be left flat on the ground until dry, using more space, taking longer to dry and often becoming further distorted.



A new improved method of moulding with just clay and water demands development of five features:

The facility to mould with stiffer clay so that the brick can be set to dry on edge rather than on the flat to lessen drying distortions, (attempts to use stiffer clay with the present method would just lead to the brick sticking fast in the mould).

The means to avoid the splashing which makes present slopmoulding such an uncongenial operation.

A technique for preventing the brick from picking up surface material from the drying ground.

The facility to handle the slop bricks when still wet so as to remove the present inefficient practice of carrying the bricks in the mould to the drying ground.

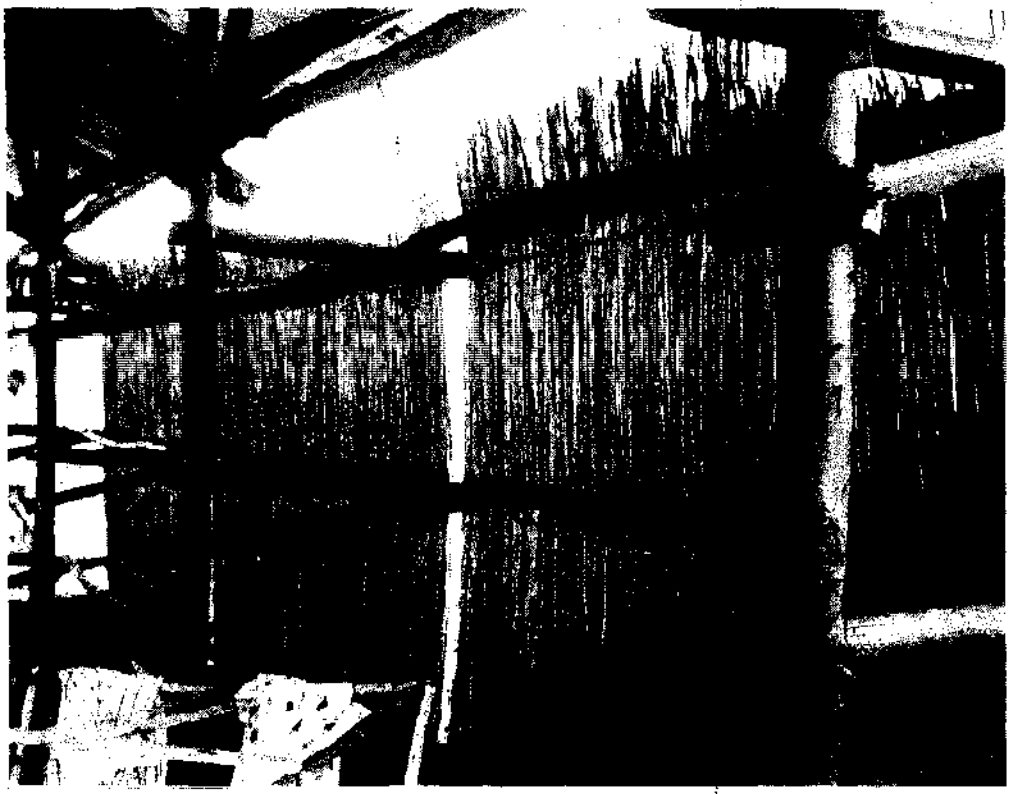
The facility to print the brickworks' name or manufacturers' mark in the frog of the brick because of the psychological effect this has on attitudes to quality. Managers and workers seeing 'their' bricks being used in buildings, feel a greater sense of responsibility than they do if once despatched the bricks become anonymous.

Improvements to drying systems.

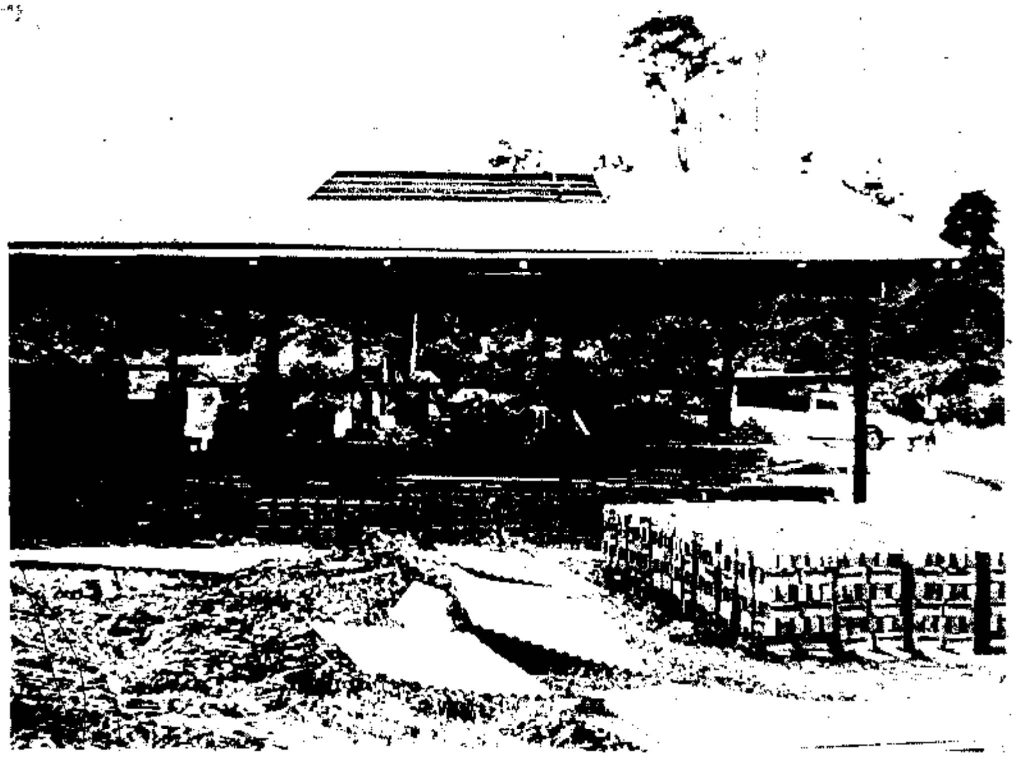
The priority for improving methods of drying centres on the need to adjust as far as possible for the variations in natural conditions. Highly mechanised brickmaking achieves this by creating a totally artificial atmosphere of low humidity, warmth and air movement, by a combination of fans, heaters and systems to re-circulate kiln waste heat. For traditional brickmaking the most promising line of approach is in the design of a building with special features which would enable it to either enhance or restrict the movement of natural air currents, to adjust levels if practicable, and divert some of the waste heat from the clamp to assist the bricks to dry. In some countries brickmaking is likely to remain an essentially itinerant activity so the need here is for the drying building to suit being readily taken down and moved to a new clay deposit.

During the period of the wet season in most developing countries, the weather pattern includes plenty of dry spells which need to be fully utilised, in accelerating the brick drying process. One procedure already introduced into a few plants is to move packs of 'green hard' but still damp bricks out into the sun, using a specially designed truck. This

DEVELOPMENT OF TECHNIQUES FOR WET AND DRY SEASON DRYING OF BRICKS



Adjustable and removable bamboo mats installed to modify the movement of air through drying sheds



Transportable packs of green bricks set out in sun for final drying

Special hand trucks developed to move drying packs, only suitable for good ground conditions larger wheeled version needed for soft ground activity could be affected by the condition of the ground but a truck with sufficiently large wheels should be able to cope with conditions in most brick yards. This does not yet solve the problem of newly moulded bricks which are too wet to stack and so a system of movable racks is required which would facilitate the rapid movement of wet bricks into external drying conditions to take advantage of a dry spell in the rainy season.

Developments so far have only gone part way to evolving a suitable system for moving bricks, and more work along these lines is required together with the development of an adjustable and possibly a transportable drying building.

Improvements to the methods of firing bricks

The greatest emphasis needed under the heating of firing is to minimise the fuel requirement where this relates to coal or oil which have to be purchased, or firewood which needs to be gathered, frequently in conditions of increasing scarcity. A major contribution to firing efficiency is to ensure that all bricks reaching the kiln or clamp are fully dried so that fuel is not wasted completing a process which should have been done naturally.

The next priority is to increase the efficiency of the firing process itself which can be achieved in several ways:

Introduction of continuous firing along the lines of the India and Pakistan industries would provide the greatest step forward in efficiency of fuel use. This option is only immediately available for those industries with access to a granular fuel such as coal which suits top feeding. The process may also be feasible using waste materials such as chaff or sawdust and this should be investigated. Continuous kiln firing either using fixed-arch Hoffman kilns or rubble-topped Bull's Trench kilns demands the establishment of enterprises large enough to generate the 10 000 or so bricks a day needed to keep such kilns running. This is far too large for many situations and a new design of small scale continuous kiln is needed and in particular, one which can be fired with scrub timber. This development needs to be given a very high priority.

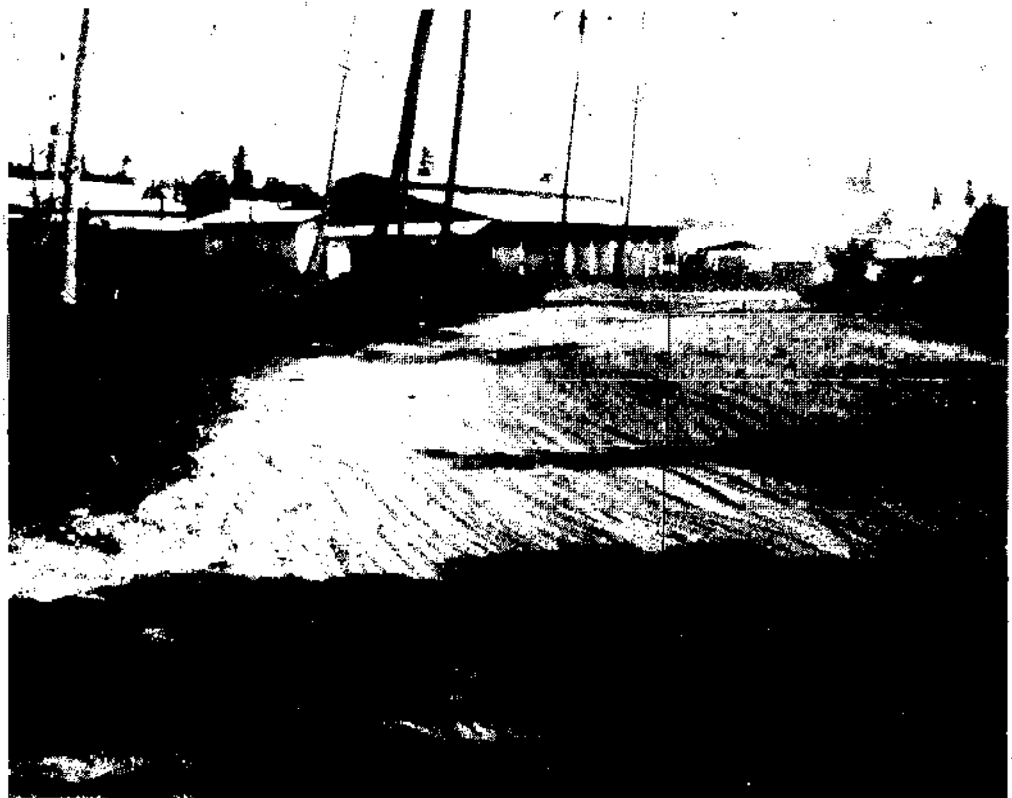
Pairing with other industries whose processes could have complementary aspects should be investigated. Charcoal production generates inflammable waste gases which may be usable for firing bricks. Animal dung is a potential source of methane as well as fertilizer, and the former might be taken off to burn bricks leaving the latter for argicultural use. These technologies merit early development.

Incorporation of carbonaceous matter into the brick clay itself is an established means of reducing the external fuel requirement but little is yet known about what the ideal proportions of different materials should be when applied to clamp or simple kiln burning. This could also be the subject of a useful study.

In the operation of woodfired clamps considerable fuel wastage is caused by poor insulation of the clamps against loss of heat through surface radiation and through exposure to the cooling effect of wind. These can be remedied by operation of known methods. However, more than any other cause, the major loss is from too much excess air being drawn into the clamp through the open ends of the firing tunnels. This calls for the development of an efficient hearth and grate able to burn irregularly sized pieces of wood while letting through the minimum amount of excess air.

The most extreme solution where all types of fuel are becoming too scarce to burn bricks with, is to seek ways of continuing brick production but to abandon the firing stage altogether. The research and development effort here will need to go into ways of stabilising or protecting unbaked bricks so that they can still constitute a permanent building material.

IMPROVEMENTS TO TECHNOLOGY OF BURNING BRICKS
ADDITION OF COMBUSTIBLE MATERIALS TO THE CLAY



Typical dump of seed husks spread outside mill in East Africa may be a possible source of fuel additive to clay or be burnt externally in top fired kiln

Addition of coal or clinker lumps to the clay may harm the appearance and strength of the finished bricks if the lumps are too big and create intrusions of ash. This process would be made acceptable if a simple grinding system were available to reduce the particle size

IMPROVEMENTS TO TECHNOLOGY OF BURNING BRICKS

REQUIREMENT FOR EFFICIENT WOODBURNING HEARTH AND GRATE FOR KILNS AND CLAMPS

Woodfired kiln in Ghana showing steel plates used to restrict some of the ingress of excess air. Metal grate originally installed has since been removed to ease stoking with long pieces of wood

Grates in use in coal fired kiln but excess air can still enter at top and arrangement would not suit woodburning

Improvements to handling systems

Levels of productivity in brick plants vary over an extremely wide range as was described in Parts B and D. In the areas where labour is most inefficiently used the factor which is usually responsible for excessive manning is the movement of materials and bricks in between processes. Under one system a worker's time may be occupied moving only two bricks while under another a simple piece of equipment enables a similar man to transport 40 bricks. The same range of efficiency occurs in the movement of clay and of water. Work place layouts are not so extreme in their range of efficiencies as the process flow is a simple one and it is difficult to take too many unnecessary journeys in the course of an activity.

The great range of productivity observed between different traditional brickmaking enterprises each operating with only rudimentary equipment indicates that there must be considerable opportunities for assisting the worst performers to become more efficient. What is needed is a fully integrated handling system using simple and robust equipment which increases the amount of effective work that people can do without hardship. In development of this equipment full attention should be given to the technical process requirements outlined above and to aspects of the environment and of ergonomics which make the occupations as congenial as possible in the conditions prevailing.

Priority projects

Of the various items in the technology of traditional brickmaking which are in need of research and development work to bring about improvement, three items stand out as requiring the most urgent attention:

A moulding system able to produce an accurately shaped, 'trade-marked' slopmoulded brick which is stiff enough after moulding to stand on edge and able to withstand pallet handling in the green state without damage.

A simple grinding and screening system capable of reducing brickmaking raw material down to less than 3 mm diameter generally, or less than 2 mm if limestone is present in the clay, coupled with a practical system for wetting and tempering the clay for up to 24 hours.

A simple small-scale continuous kiln achieving better fuel utilisation than is possible with intermittent kilns and clamps and which is capable of utilising a variety of waste materials, either as kiln fuel or incorporated as carbonaceous matter in the clay itself. This development work could also include improved designs for a hearth and grate for more efficient wood firing for use with either kiln or clamp.