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DEVELOPMENT OF LATERITE BUILDING MATERIAL INDUSTRY

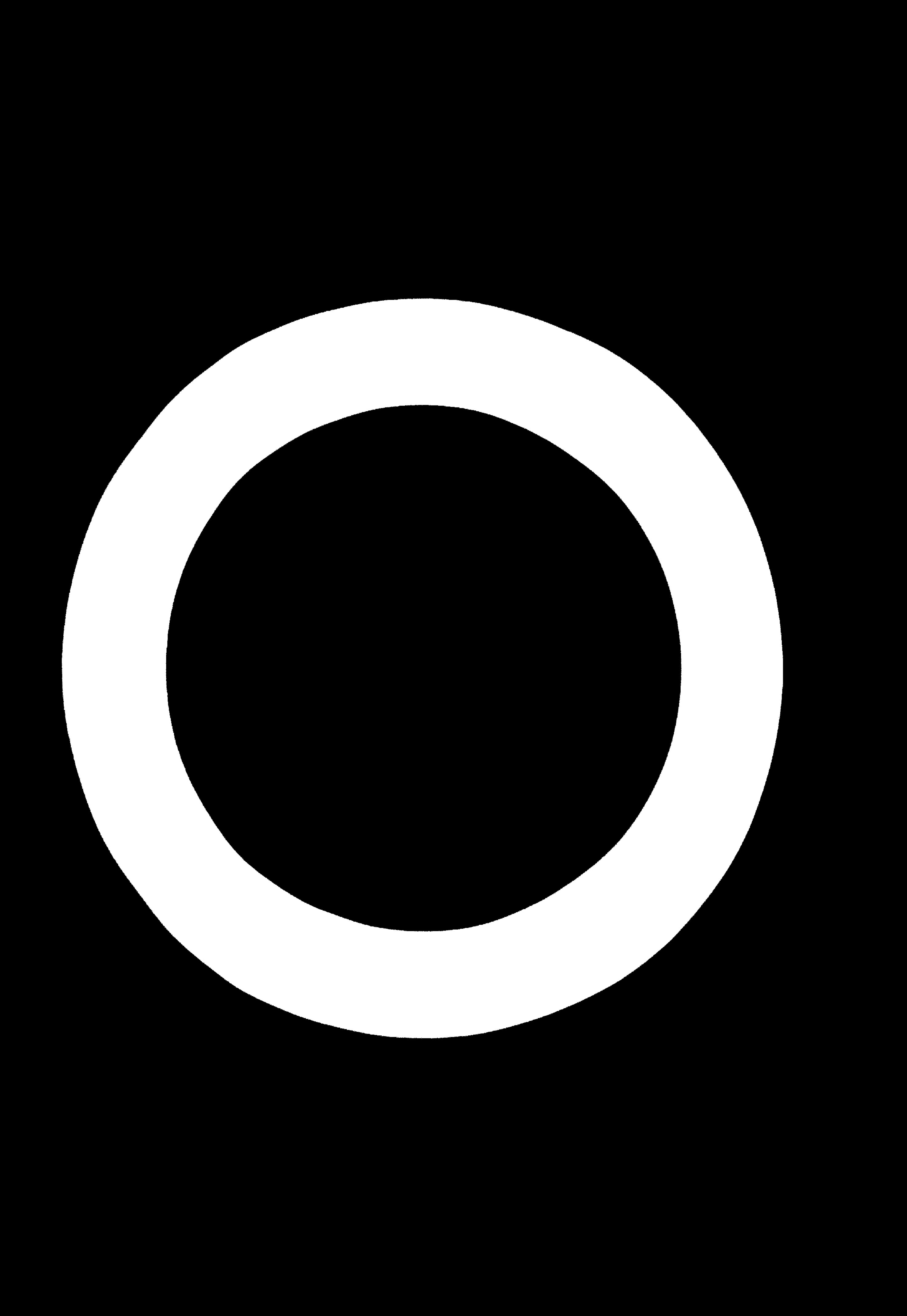
DP/MLW/74/001

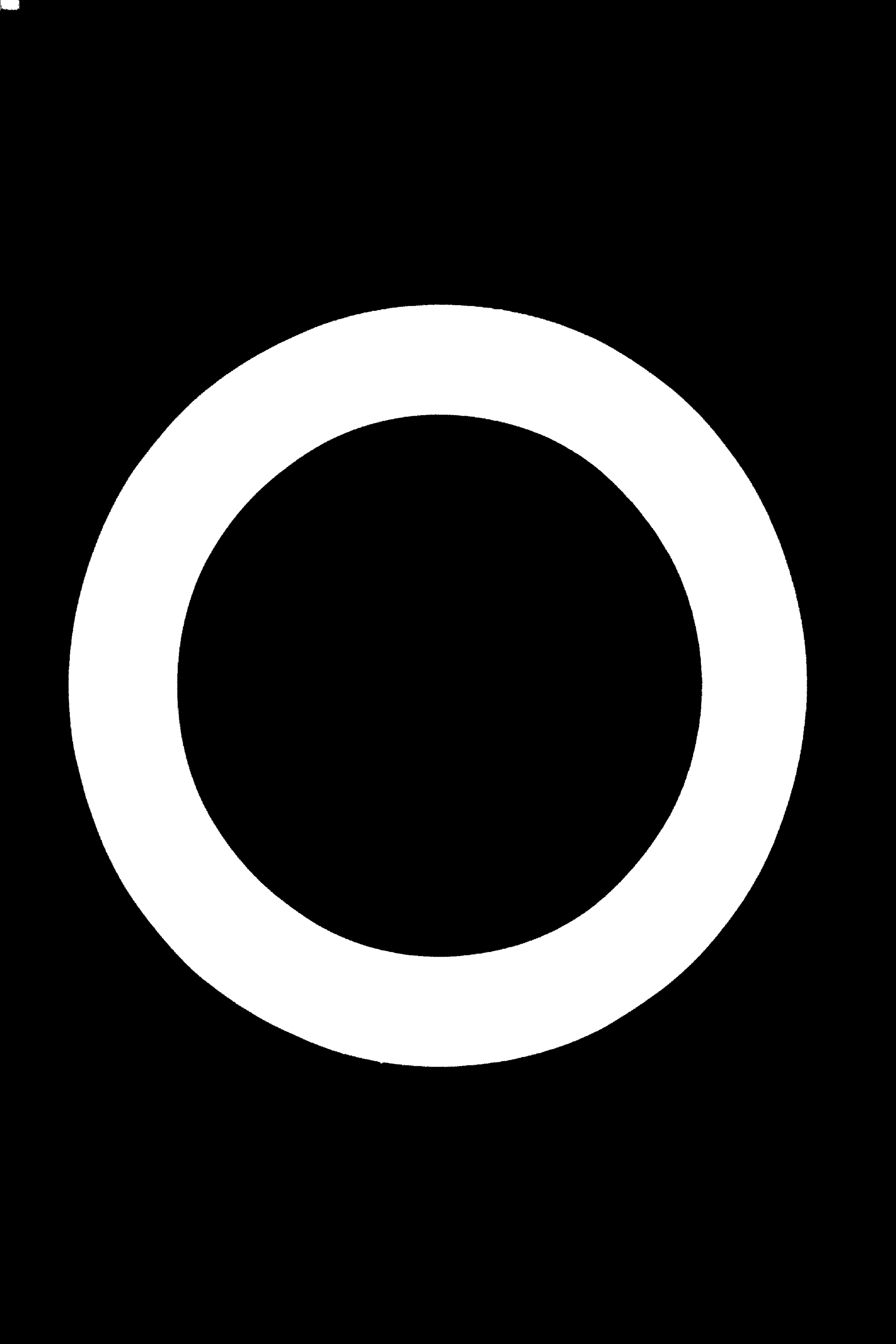
MALAWI

TERMINAL REPORT

Prepared for the Government of Malawi by the
United Nations Industrial Development Organization,
executing agency for the
United Nations Development Programme

United Nations Industrial Development Organization





United Nations Development Programme

DEVELOPMENT OF LATERITE BUILDING MATERIAL INDUSTRY

DP/MLW/74/001

MALAWI

Project findings and recommendations

Prepared for the Government of Malawi
by the United Nations Industrial Development Organization,
executing agency for the United Nations Development Programme

Based on the work of Jan Bondam, expert on laterite building materials

United Nations Industrial Development Organization
Vienna, 1975

Explanatory notes

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

References to "dollars" ($) indicates United States dollars, unless otherwise stated.

The monetary unit in Malawi is the kwacha (K). A tambala (t) is a hundredth part of a kwacha. During the period of the report the value of the kwacha in relation to the United States dollar was $US 1 = K 0.83.

The following abbreviations are used in this report:

Btu	British thermal unit
kcal	kilocalorie
kgf	kilogram force
MHC	Malawi Housing Corporation
m.t.	Metric tons

CONTENTS

Tables

Figures

INTRODUCTION

In 1974 the Government of Malawi decided to request the assistance of the United Nations Development Programme (UNDP) in investigating the possibility of introducing and establishing industrial production of low-cost building materials based on available lateritic soil as the principal raw material.

The immediate objectives of such a study were:

(a) To estimate the market potential and to confirm raw material availability;

(b) To propose means of organizing a viable industry, emphasizing small-scale and cottage industry aspects, while safeguarding the interests of existing indigenous brick producers.

Limited experiments as to the use of soil-based building materials had earlier been conducted in the Blantyre area, but the results had been considered inconclusive.

Upon the arrival of the expert in Malawi on 18 July, it became evident that the most advantageous approach to the Government's request was to co-operate with the Malawi Housing Corporation (MHC) which provides site and service facilities in the traditional housing areas.

At a meeting with the Permanent Secretary of the Ministry of Trade, Industry and Tourism, the expert submitted a plan to evaluate the properties of the available soils for making building-blocks to be used in areas allocated to possible high-density traditional housing schemes in the vicinity of a number of towns throughout Malawi. The designated areas are near Blantyre, Zomba, Balaka, Lilongwe, Salima, Chintheche, Mzuzu, Karonga and Ngabu.

The Work Plan included a demonstration of the basic techniques used in making soil building blocks. For practical reasons an area near Lilongwe was chosen.

Facilities were made available at the headquarters of the MHC in Blantyre. The field trip was arranged by the Ministry of Trade, Industry and Tourism. The determination of physical soil properties' suitability was carried out at the Materials Laboratory, Ministry of Works and Supplies, in Lilongwe. The compressive strength of a sample of the blocks made at the demonstration was measured at the same laboratory.

Terminology

The term, "laterite" has been introduced and widely accepted for tropical or sub-tropical soil, irrespective of whether it is a true laterite or not. Frequently the term is modified to laterite soil for the red-brown to dark-brown soils of these climatic zones. The neutral word "soil" has been indiscriminately used for any kind of upper earth level. The physical and mechanical properties of a soil will eventually determine whether it can be used as a source for building materials, and the properties of interest for this study are the grading and the plasticity index.

The terms "stabilized soil" or "cement-stabilized soil" has been used for any soil to which is added a stabilizing agent, commonly cement or lime, to improve the compressive strength of compacted soil blocks when cured in the proper way.

A wide range of soils, irrespective of their appearance, are suitable for applying stabilization techniques to produce a reasonably strong building material. This does not exclude that a particular soil will produce a stronger block than any other, but it has not been considered of importance to restrict the study to optimal conditions because the object in each case will be to utilize locally available soils under local conditions. Obtaining optimum results from each particular soil is the subject of building material research, not of an assessment of the methods and means.

I. FINDINGS

The traditional way of building homes in the rural areas and townships of Malawi is largely based on sun-dried, locally available soils, either in a mud-and-wattle construction or by utilizing sun-dried blocks, so-called Kimberley blocks, wet-shaped in moulds by hand.

These building methods and materials may offer excellent shelter and convenient, low-cost one-storey housing, but the nature of the materials is such that the constructions are comparatively shortlived. Improvements by way of cement or a lime plaster for the outer walls, more roof overhang and the provision of a solid course may prolong the life-expectation of mud-based homes.

Durable building materials like concrete, cement blocks, or fired bricks are to a large extent beyond the reach of a major part of the population because they are too expensive in terms of initial outlay. No alternative durable, low-cost building material is at present available for traditional housing purposes.

It has therefore been suggested that the introduction of cement-stabilized soil into the manufacture of building materials can become the starting-point for improved housing in areas where traditional building takes place if the soils can be utilized on site to provide construction elements, whether for foundations, external or internal walls, or floors. However, contrary to traditional methods of building, the utilization of stabilized soil building materials requires an input of cement or lime from outside the area. This will add considerably to the material costs as compared with the popular, low-cost Kimberley blocks building material.

The manufacture of cement-stabilized soil blocks requires a number of skills, but any individual builder could do the necessary operations, which are similar to those used in making of Kimberley blocks, by hand, using a wooden or iron mould and shuttering the soil cement mixture for compaction. Again, small building enterprises could buy or rent small-scale, removable compaction equipment, such as the Cinva Ram,[1/] which is simple to operate. If desired,

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1/ Registered trade mark, International Basic Equipment Corporation (IBEC), New York; manufactured by Metalibec Ltda, Bucazamanga, Colombia.

operations like digging, mixing, shaping, and compaction of the ready-mix could all be partly or fully mechanized. The production methods as a whole can be made labour-intensive, which under the given circumstances may be an advantage.

A disadvantage of this method of production is that the quality of the ready-mix has to be rather closely watched so as to avoid a waste of cement, relatively the most expensive compound used. The frequent tests that have to be made are, however, of a simple nature and can be carried out on the spot.

The following sections are devoted to a variety of aspects connected with the use of cement-stabilized soils for building purposes, particularly in the traditional housing sectors of Malawi.

A. Cement-stabilized soil: preparation and applications

The manufacture of stabilized-soil building materials is an extension and an improvement on soil-stabilization methods used in road construction.

The aim is to obtain a more durable material by binding the soil particles with cement or lime and shaping the ready-mix into blocks by compaction, usually with the aid of a block press.

Choice of raw material

Although a wide range of soils are suitable for shaping cement-stabilized blocks, experiments have shown that to obtain sufficient strength the following simple raw material criteria must be observed:

(a) The soil must be readily friable upon drying;

(b) The soil-cement mix should be sufficiently cohesive to allow handling immediately after moulding;

(c) The shaped blocks should dry without destructive shrinkage and cracking.

Requirements (a) and (c) put an upper limit to the content of fines, i.e., clay fraction particles below 0.06 mm (200 mesh), in the soil. Requirement (b) sets a lower limit for the desirable clay content.

Under insufficiently controlled conditions an increasing content of fines decreases the strength of the blocks at a given cement addition.

Clay-rich soils hamper the preliminary stages, such as digging, drying, screening, and finally mixing, and therefore require a disproportionally high labour input.

In general the soils should be inorganic sandy clay or clayey sands of low to medium plasticity. Their combined silt and clay fractions should preferably between 5 and 15 per cent when determined. Soils with a more than 60 per cent content of particles below 0.06 mm (200 mesh) should be avoided. The plasticity index should be between 10 and 15. Bearing in mind that for most practical purposes only visual inspection of the available soil is feasible, it is important to be able to recognize suitable soils by simple testing on the spot. A test of this nature is described in annex I.

The shaping of blocks and other building materials

Basically, any shape that can be obtained by means of a press can be made of cement-stabilized soil. By far the largest volume of ordinary building materials consists of rectangular solid blocks of different sizes. These are made on the building site from cement-stabilized soil by using a hand-operated, movable press of simple design which is commercially available.

Hand-moulding of blocks can also take place and, properly performed, will give acceptable results. The procedures to be followed in making cement-stabilized soil blocks are given in annex II. The technical limitations on cement-stabilized soil blocks are reviewed in annex III.

Otherwise the use of cement-stabilized soil is only restricted to those shapes which are compatible with so-called "green strength", i.e., the strength of the body immediately after shaping, so as to be capable of handling and curing without distortion. That is why a wider application of cement-stabilised soil for other than solid rectangular blocks needs a more sophisticated test of the available soil's physical properties or its careful choice as regards any specific use in order to meet the requirements as to uniformity of the finished products. This holds good in particular for more elaborate shapes, like hollow blocks which eventually can only be produced on an industrial scale.

Special applications, which include use as quarries and other tiles, are mentioned because they present an opportunity for small-scale industrial ventures and a market for these products, especially their employment in industrial buildings and workshops in urban areas, may become available in the existent permanent building sector.

While the making of blocks on sites is the major ordinary use that can be made of cement-stabilized soils, it is in the interest of the Malawi building material industry that technology should be introduced and utilize the country's own readily available raw materials in such a way as to put small-scale industry in a position to compete also in quality with imported and other domestic materials.

Masonry building materials made of cement-stabilized soil can in principle be used in exactly the same way or in combination with materials like brick, cement blocks, and concrete prefabricated units. Depending on their compressive strength, soil-based materials can be used for any type of construction in which an alternative building material is available or desirable.

Cement-stabilized soil, in the shape of rectangular building blocks, precise dimensions, and a smooth surface when pressed, is particularly well-suited for external walls in one-storey industrial constructions like sheds and workshops as well as for one-family houses.

B. Organization of viable production units

The manufacture of cement-stabilized soil blocks can be undertaken by individuals or families or in collaboration with neighbours, by contractors or local bricklayers, on a more extensive scale by firms specializing in the sale of building materials, or on an industrial scale. In general, though, it represents an on-the-spot utilization of soils and is therefore more or less confined to specifically local enterprises or to mobile ones geared to on-the-spot manufacture and delivery.

Basic equipment

To give some idea of the capital investment needed for making cement-stabilized soil blocks, the basic tools used in the process, together with alternative machinery for further mechanization, have been listed in table 1. No cost estimates are included because these vary widely in accordance with the scale of operations. This becomes clear from the items listed in the table.

From the commercial point of view any small enterprise operating in this field must recognize that its product competes with existing building materials, mainly Kimberley blocks and bricks, for ordinary housing. To be competitive, the product must be able to meet the pressing need for a good quality material at lowest possible cost. The achievement of this goal necessitates that viable units shall be organized in such a way that (a) they are mobile and equipped to produce blocks on the spot of locally available raw materials and (b) they maintain a uniform high quality of product.

Table 1. Equipment for making cement-stabilized soil blocks

Operation	Basic equipment	Alternative equipment for small enterprises
Digging	Pick, shovel, hoe	Tractor-mounted gear for digging
Drying	Shovel for turning the soil; rake for spreading	Tractor-mounted gear for raking
Screening	10 mm (3/8") mounted wire-mesh screen of 1.0 x 0.6 m (1/4" can also be used)	Jigger - preferably hand-operated, with same screen sizes
Mixing	Bucket for measuring quantities by volume; watering can (tin with pinholes); board (flat hard surface); shovel; cover materials (grass, old jute or cement bags)	Spring balance or other device for weighing quantities; watering cans, metal sheets or stabilized ground; concrete mixer; covering material
Compaction (shaping)	Handmould with hinges made from hardwood or plate iron, scoop	Block press, capable of producing blocks with a dry density of about 1.8 g/cm^3; necessary tools and lubricants
Curing	Cover materials (see above); watering can	Cover materials; watering can

Knowledge of the soil properties, rigid quality control throughout the process of manufacture, and a uniform way of processing are prerequisites for any successful venture of this kind. For purely commercial purposes exclusive use of a block press, and no hand-moulding, is advisable.

A team should consist of not less than two workers, with the senior trained to test the available soil, control the preparation of the batch, and operate as well as maintain the press. It is estimated that a steadily working team of two can easily produce an average of 150 blocks (dimensions 290 x 140 x 120 mm) during an 8-hour working day, all operations included, at the site. Using a cement-to-soil ratio of 1:15 (7 per cent), some 100 blocks can be made per bag of cement. For average production cost estimates, see section C.

Manufacture of hollow blocks on an industrial scale

The use of stabilizing processes in the manufacture of large prefabricated building units in an industrial plant is only feasible on a large scale. A minimum output corresponding to an annual production of 10 million standard bricks (240 x 120 x 70 mm, weight approximately 3 kg) should serve as a basis for calculation. The annual raw-material consumption of such a minimum size plant is about 10 million x 3 kg = 30 million kg = 30,000 tons.

The following is a rough estimate for the outlay on a plant with an annual production of 25,000 m^3 of hollow blocks, size 365 x 240 x 238 mm, weight about 30 kg each. That amounts to an annual production of 1.2 million blocks, total weight 36,000 tons. The calculation is based on the use of lime as the stabilizing agent. Only basic equipment is itemized.

Capital investment

1. Milling equipment (cone crusher or hammer mill will be sufficient)	K 8,000.00
2. Double-shaft mixer	5,600.00
3. Hydraulic press, capacity 500 blocks/hour	45,000.00
4. Autoclaves (or other curing facility)	3,000.00
5. Sundry equipment (silos etc.)	2,400.00
6. Shed and service facilities	16,000.00
7. Working capital	20,000.00
Total	K 100,000.00

These are figures for the production plant only. Should a pit be operated under the same management, additional moving equipment for handling an annual consumption of about 40,000 tons of lateritic soil and 4,500 tons of lime will be necessary.

The plant will operate with an annual electrical energy requirement of about 80,000 kWh. The labour force will be approximately 20 workers, the majority of whom will handle ready blocks. On a basis of 300 working days the daily production will be 4,000 hollow blocks.

Production cost estimate

The production cost is calculated for 1 m^3 of hollow blocks, which comprises about 50 blocks with a dry weight of 1,500 kg.

1.	Raw materials (1:9 mix)...................................	K 4.68
2.	Labour...	0.20
3.	Electrical energy (3 kWh)..................................	0.10
4.	Depreciation (10 years)....................................	0.42
5.	Repayment and interest (5 years, 10%).....................	0.22
6.	Administration...	0.40
7.	Miscellaneous items (5%)..................................	0.31
	Total	K 6.33/m^3

With a dry relative density of 1.9, the production costs for each metric ton will be K 3.33. Although the calculation lays no claim to perfection, it is evident that the cost of lime, in this calculation K 24.00/m.t. against K 0.80/m.t. for the lateritic soil, is the dominate cost factor. For that reason it will be worthwhile investigating whether a plant of this kind could operate in conjuction with a lime kiln.2/ In such a case the situation of limestone will determine the site.

Additives other than lime could be chosen, but these will only inflate the production costs.

A pilot plant could perhaps be established near Lilongwe where an appreciable market for building materials, mainly in the public construction sector, is developing. A plant of this kind could conveniently prouuce other non-ceramic building materials, like concrete blocks, which have already been accepted in the building trade. A feasibility study at a chosen site will be necessary before a final decision can be reached.

C. Evaluation of the economic aspects of building in Malawi urban areas

Organisation

The Malawi building industry is to a great extent organised on conventioanl lines. There are well-established, large, internationally-based contractors

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2/ A wide range of lime kilns is available. For further reference, see G. E. Bassey, "Production and use of lime in the developing countries", Overseas Building Notes, No. 161, 1975.

in the public sector, smaller-scale firms, one-man businesses, and private individuals who act on the do-it-yourself principle.

The Government's influence in the industry is considerable, partly through full or part-ownership of companies, but mainly by contract awards. Its permanent housing activity in urban areas, through the MHC, occurs alongside of other building activities.

The second largest influence consists of commercial enterprises and industrial corporations which need retail outlets, storage facilities, factories and workshops.

The industry's current structure is undoubtedly such, that its activities are geared to the needs and wants of the Government, public bodies, and industry in respect of permanent construction and permanent housing because in the private sector the demand for permanent housing, though growing fast, is at present, limited, being mainly determined by available savings (or the possibility of obtaining loans) and the level of population income. The basic need for housing is met by traditional building methods and includes any semi-permanent or temporary domestic structure.

<u>Size of the building industry</u>

The size of the industry is indicated by its consumption of building materials, parts of which have to be imported. Table 2 summarizes the sales and imports in recent years of some commonly used materials in recent years.

The registered volume of buildings completed from 1969 to 1974 is summarized in table 3. It covers governmental, public bodies, and industrial construction, permanent housing by governmental and local authorities and industry as well as private domestic building.

These tables give a rough but adequate picture of the industry's present state. Mainly operative in the public sector, it is capable of meeting the challenge of further growth by providing the permanent buildings necessary for urban development.

Cost consciousness and market potential will determine whether building materials based on stabilised soil are accepted in the public sector.

Further aspects of building costs will deal only with housing in the private sector.

The private sector

Estimates of the total volume of housing completed in the private sector are very elusive. Whereas the consumption of corrugated iron sheets for roofing can to some extent be used as an indicator, to gain a clear picture as to the consumption of bulk materials like cement and bricks is hardly possible.

Table 2. Imports of building materials in Malawi, 1971-1973
(Kwacha)

Item	1971	1972	1973
Roofing sheets, iron aluminium, asbestos-cement	1 206 597	1 830 475	1 907 341
Iron bars, rods, angles	925 157	826 964	748 780
Iron tubes and pipes	350 919	483 555	385 814
Iron door and window frames	174 294	30 222	103 884
Ceramic ware, tiles, pipes	167 117	212 796	370 772
Building materials of bonded wood and mineral	4 963	15 488	24 125

Source: Various statistical bulletins published by the National Statistical Office, Zomba.

Table 3. Value of buildings completed in Malawi, 1969-1974
(Millions of kwachas at current prices)

Location and/or builder	1969	1970	1971	1972	1973	1974
Private contractor	19.0	16.8	12.8	13.9	18.9	21.9
Ministry of Works	4.1	4.4	6.8	10.9	11.1	9.5
Blantyre, private sector	5.0	3.9	3.5	4.2	2.2	2.3
Lilongwe, private sector	0.4	1.6	0.4	0.6	0.6	1.4
Cement sales in 1,000 tons	83.6	77.5	71.6	81.1	93.3	91.9

Types of housing

In 1971 a useful study of the types of housing was made for the MHC in two traditional housing areas, Ndisande and Zingwanga, and in the squatters' area of Bangwe, all near Blantyre. The total figures are shown in table 4.

Table 4. Distribution of house types in three areas near Blantyre, 1971 (Percentage)

Type of house	Ndizande (Average covered floor area: 85.2 m^2)	Zingwanga (Average covered floor area: 72.4 m^2)	Bangwe
Mud and wattle	51.0	66.2	95.3
Kimberley blocks	35.3	29.3	4.7
Brick (concrete and fired)	13.7	4.5	-
Total	100.0	100.0	100.0
Covered by iron sheet roofs	83.9	55.1	40.7

Source: Malawi Housing Corporation, 1971.

The three areas differ considerably, and it is clear that only very temporary housing exists among squatters in the Bangwe area. The marked difference between the Ndizande and the Zingwanga areas may reflect the prevalent level of income, age groups distribution, year of settlement, etc. The data collected are not conclusive.

A renewed survey may very well indicate the urge towards improved housing reflected in the gradual abandonment of the mud-and-wattle type of construction in areas allocated to traditional housing schemes.

Economics of traditional housing

A 1972 study[3/] by the MHC examined the economics of traditional housing areas as regards site and service schemes, with the annual income of plot-holders ranging from nil to K 600 per annum. It concluded that "the private sector element represents 32.5 per cent of the total population" of the income groups within the K 100 - K 600 range who can afford to pay "the economic plot rent at the compromise rate of K 2.30 per month, inclusive of municipal rates". The study indicated that 22.6 per cent of the population cannot afford these rates.

As the above calculations are based on a minimum investment of K 60 in house-building, necessary for temporary housing over 2 years, it becomes clear that utilisation of cement-stabilised soil blocks instead of traditional mud-and-wattle of Kimberley blocks will only be within immediate reach of the upper income bracket (K 400 - K 600 per annum) of the low income group which occupies

3/ D. B. Mills, An Assessment of the Economics of Traditional Housing Areas (Site and Service Schemes), (Zomba, Malawi Housing Corporation, 1972).

the traditional housing areas. This bracket comprises 6.2 per cent of the population. The conclusion is based on the fact that cement-stabilized soil blocks cost 3.6 times more than Kimberley blocks and that a minimum of one year's income will be spent on attaining to domestic ownership. The gradual replacement of temporary homes by more permanent ones seems to be in accordance with this figure.

The survey of the Ndizande area near Blantyre, indicated that 13.7 per c cent of homes erected are of durable materials. In the Zingwanga area the figure was only 4.5 per cent.

If any conclusion is drawn, and this can only be done very tentatively, it is that at present about one tenth of the population in the urbanized areas of traditional housing will be in a position to use durable materials, usually fired brick, for building their homes. The saving through cement-stabilized soil blocks made on site instead of ordinary brick would be approximately only 20 per cent on the total cost of a modest house. This is not considered adequate to bring more durable building materials within the reach of an appreciable number of urban dwellers unless a policy to stimulate the use of such materials is adopted in urban development in order to improve the general standard in the high-density traditional housing areas.

<u>Average production cost estimates</u>

A comparison between the estimated average production costs for making one thousand units each of certain standard building materials, Kimberley blocks, bricks, and cement-stabilised soil blocks, follows. Outlay on locally available soils has been disregarded because their employment would take place on site, but excavation costs have been included. Labour costs are based on a daily wage of 50 tambalas ($0.60). Unskilled labour can be employed in all instances.

(a) <u>Kimberley blocks</u>

Average size per unit: 300 x 160 x 140 mm

Average weight per unit: 6.75 kg

Average face per unit: 420 cm^2

Assumed daily production: 160 blocks by 2 labourers
Production costs per 1,000 units:

Labour..............................	K 6.25
Other costs..........................	0.10
Breakage 20%.........................	1.27
Total	K 7.62

"Labour" includes digging, mixing, shaping, stacking. "Other costs" include use of tools.

(b) Fired bricks

Average size per unit: 240 x 120 x 70 mm

Average weight per unit: 3.00 kg

Average face per unit: 170 cm^2

Assumed daily production: 1,500 bricks, firing included, by 6.5 labourers

Production costs per 1,000 units:

Labour...............................	K	5.41
Fuel...............................		2.00
Other costs...............................		0.20
Capital interest...............................		0.12
Breakage 30%...............................		2.29
Total	K	10.05

"Other costs" include fees, depreciation of tools, and water. Capital interest, at a 10%/year interest rate, is calculated for 6 weeks, producing approximately 100,000 bricks by 2 labour units. Fuel costs are estimated assuming that the caloric value of the fuel wood is 3,000 kcal/kg = 5,500 Btu/lb. The reason for a high breakage is the inadequate firing technique when producing bricks in huge piles of 100,000 bricks or more. In smaller piles this figure is lower and may be only 10% in a successful firing.

(c) Cement-stabilized soil blocks

Average size per unit: 290 x 140 x 120 mm

Average weight per unit: 8.25 kg

Average face per unit: 406 cm^2

Assumed daily production: 160 blocks by 2 labourers using a block press and simple tools

Production costs per 1,000 units:

Labour...............................	K	6.25
Cement...............................		20.00
Other costs...............................		0.30
Total	K	26.25

"Labour" includes digging, screening, mixing, pressing curing and stacking. With a mix of 1:15, about 100 blocks can be produced from one bag of cement. The cost of cement is K 2 for 50 kg. Breakage is negligible. "Other costs" include depreciation, hire purchase, maintenance, tools.

A more realistic comparison is obtained by re-calculating the average production costs per 1,000 units in costs per metric ton and costs per square metre of wall face. The figures, together with those for hollow blocks, are listed in table 4.

From these figures it can be deduced that, simply as a matter of production costs, cement-stabilized soil blocks offer no low-cost alternative to indigenous brickmaking. The use of soil blocks can only be motivated by saving on delivery costs to the building site. Employment of cement-stabilized soil blocks may for that reason become sufficiently attractive in some of the existing areas of traditional housing around the main centres of urban development, Blantyre and Lilongwe, and in some future urbanized areas.

Cost of transportation

The over-all costs of transportation in Malawi average K 0.20/ton-km. To these have to be added loading and unloading costs, producer profits, and in some cases retail profits.

Bricks are sold for K 12.00 per 1,000 in the Blantyre area; their weight is approximately 3 tons.

The costs for 1,000 bricks delivered at building sites at various distances from a brickwork are listed in table 5.

Table 5. Cost of bricks delivered to sites at various distances from the works (Kwachas per 1,000 bricks)

Cost item	10 km	20 km	30 km
Transportation	6.00	12.00	18.00
Price at works	12.00	12.00	12.00
Labour (4h)	0.25	0.25	0.25
Total	18.25	24.25	30.25

Taking the nearest distance only, the saving in using cement-stabilised blocks instead of bricks becomes apparent. The costs will still be K 0.65/m^2 wall face for cement-stabilised blocks, but K 1.07/m^2 for bricks. In rural areas the use of bricks will remain cheaper than that of cement-stabilised soil blocks because bricks can still be produced near to building sites.

It should be noted that hollow blocks are in no way a competitive alternative to bricks for ordinary housing although they may be an alternative in multi-storey permanent housing as compared to the use of concrete blocks.

Building costs, using cement-stabilized soil blocks as compared to Kimberley blocks

A comparison of actual building costs is hampered by lack of wide experience in building with cement-stabilized soil blocks. A number of assumptions have to be made as to the labour involved in erecting a house with standard soil blocks (290 x 140 x 120 mm) as compared with using ordinary brick. Saving is to be expected due to reduced cement consumption in the joints effected by the uniform size, in contrast to brick, of cement-stabilized soil blocks.

To compare qualitatively similar dwellings, it has been assumed that the house built of Kimberley blocks is plastered with cement mortar. A simple square design has been chosen: a living room, 2 bedrooms, and a kitchen with a total base area of 64 m^2. The house has 3 doors and 4 windows, is roofed with iron sheets, and has been built entirely by hired labour, with skilled labour employed for the masonry and carpentry. This is House A. House B is built of cement-stabilized soil blocks.

Table 6 shows the tentative cost breakdown based on Malawi price and wage level figures.

Table 6. Tentative break down of building costs for two prototype houses

Item	House A		House B	
	Cost (K)	Fraction of total (percentage)	Cost (K)	Fraction of total (percentage)
Labour	53	11	80	12
Foundation	5	1	23	4
External walls	90	19	147	22
Internal walls	8	2	73	11
Floor	5	1	40	6
Roof (70 m^2), including purlins	156	34	156	23
Doors and windows	144	32	144	22
Total	461	100	663	100
Total building costs per square metre	7.20		10.35	

The eye-catching difference in costs has again been caused by the high initial outlay on cement. Cement consumption is three times as high for cement to stabilize the soil blocks as it is for plastering the outer walls of the House A.

The floor of House B is of cement-stabilized soil: a cement floor in House A would add around K 30 to the total.

Saving can be made by using cement-stabilized blocks for the outer walls of House B and Kimberley blocks for the inner walls. This will economize about K 70.

Erecting each house without any help of hired labour will bring the total cost down to K 310 for House A (K 4.84/m^2), but only to K 518 for House B (K 8.09/m^2).

D. Test programme

A sampling programme in areas planned to be allocated to traditional housing schemes around a number of towns throughout the country was carried out so as to gain an impression of the suitability for making cement-stabilized blocks, from the soils commonly found in Malawi. The following localities were selected: Blantyre (2 areas, South Lunzu and Mtenje), Zomba, Balaka, Lilongwe (Area 47), Salima, Chintheche, Mzuzu, Karonga and Ngabu.

Two plots in Area 47 were chosen to demonstrate blockmaking with a Cinva Ram block press owned by MHC.

Soil sampling

Samples, about one for every 2 hectares (5 acres), were taken at random and from immediately below the layer of cultivation to a depth of about 50 cm below surface. From a large, thoroughly mixed sample about 1 kg was taken for testing at the laboratories of the Ministry of Works and Supplies in Lilongwe.

The grading and the plastic index of the soils were determined and the results are listed in annex IV.

A total of 42 samples was collected from the localities mentioned. Three additional samples, Plot Muenji 1 and Plot Chombese 23, 1 and 2, were taken at sites used for brickmaking.

Simultaneously with the sampling, the soils were tested visually according to the rules in annex I so as to obtain an impression as to the reliability for practical purposes of this method. These subjective visual estimates as to the content of fines in the soils are listed, together with the grading determined in the laboratory, in annex IV.

It appears that visual inspection, carried out according to a subjective division into coarse-grained, medium-grained and fine-grained particles which in the sieve analyses corresponds to gravel and coarse sand, fine sand, silt and clay, is correct to a maximum error of 22 per cent as compared with the determined values.

Although the soils vary appreciably in physical properties, the limits of workability, and hence their suitability for blockmaking, are only excessively exceeded in a few cases.

A short description of the available soils in the areas investigated is given in annex V.

The soils at Karonga and Ngabu are the least suitable for blockmaking. They are dark grey, unyielding sedimentary soils with a high content of fines and a plasticity index of about 18. They would need at least 25 per cent addition of coarse sand to become readily workable.

Blockmaking

A demonstration of making cement-stabilized soil blocks with a Cinva Ram block press was performed in Area 47. Two plots were chosen. At Plot 1 a batch was prepared with a cement-to-soil ratio of 1:20. From this batch 34 blocks, size 290 x 140 x 70 mm, and 11 blocks, size 290 x 140 x 110 mm, were made. At Plot 2 the batch composition was 1:15, from which 36 blocks, size 290 x 140 x 70 mm, and 5 blocks, size 290 x 140 x 110 mm, were pressed.

Curing was done in the crudest way by covering the finished blocks with grass and dry banana leaves and watering for 4 days. Very lean mixtures were used. After 12 days of curing, 7 samples were taken from Plot 1 and 6 samples from Plot 2 to test the soaked strength. One of the samples from Plot 1, No. 1-7, had been cured indoors at 100 per cent relative humidity.

Testing

The result of the tests for soaked compressive strength, done at the laboratories of the Ministry of Works and Supplies in Lilongwe, is shown in table 7.

Table 7. Soaked compressive strength of cement-stabilized soil blocks, Area 47, Lilongwe

Plot 1: batch composition 1:15
Plot 2: batch composition 1:20

Plot 1			Plot 2		
Sample number	Strength (kgf/cm^2)	Strength (lb/in^2)	Sample number	Strength (kgf/cm^2)	Strength (lb/in^2)
1-1	7.24	103	2-1	9.84	140
1-2	8.29	118	2-2	9.35	133
1-3	10.33	147	2-3	7.80	111
1-4	12.44	177	2-4	8.79	125
1-5	9.80	140	2-5	9.56	136
1-6	7.24	103	2-6	9.07	129
1-7	12.93	184			
Average a/	9.23	131	Average	9.07	129

Notes: Curing conditions: free air; blocks covered with grass and sprinkled with water for four days. Block sizes: all blocks are 290 x 140 x 70 mm, except No. 1-6 and No. 2-6, which are 290 x 140 x 110. No. 1-7 was cured indoors in a plastic bag.

a/ Excluding No. 1-7.

The dry relative density of the blocks was between 1.65 and 1.70.

Since the test was carried out under the most unsatisfactory curing conditions, i.e., those normally prevailing at an ordinary building site, its results demonstrate that it will be a waste of cement if curing is not properly performed. There was no difference in strength between the batch (Plot 1) with a composition of 1:20, and that (Plot 2) with a composition of 1:15.

The soil parameters were hardly of great influence, as can be deduced from table 4 by comparing samples Lilongwe 1 and 2.

To demonstrate the importance of careful curing, one block (1-7, table 5) from Plot 1 was cured indoors in a wet plastic bag. Its soaked compressive strength, after 10 days' curing, was 40 per cent better than that averaged by other blocks. This difference is significant.

In broad terms the conclusion to be drawn from this test is that, under conditions prevailing at a building site, a cement-stabilized soil block can after a few weeks' crude curing be obtained with a soaked compressive strength of about 10 kgf/cm^2 (140 lb/in^2). This accords with published results from elsewhere in Africa.[4]

Similar tests with the Cinva Ram block press were previously made on cement-stabilized soil blocks in the Blantyre area (MHC, South Lunzu traditional housing area, 27 February 1973). They were carried out on 5 batches, ranging in composition from 1:10 to 1:20. Only dry compressive strength was measured. No details on the soil composition have been given nor of the manner in which the blocks were cured. The results have been summarized in figure I.

4/ J. P. Moriarty and O. Thirkildsen, Lateritic Soil-Cement as a Building Material, Report No. 2 (Dar-es-Salaam, Ministry of Lands, Housing and Urban Development, 1973).

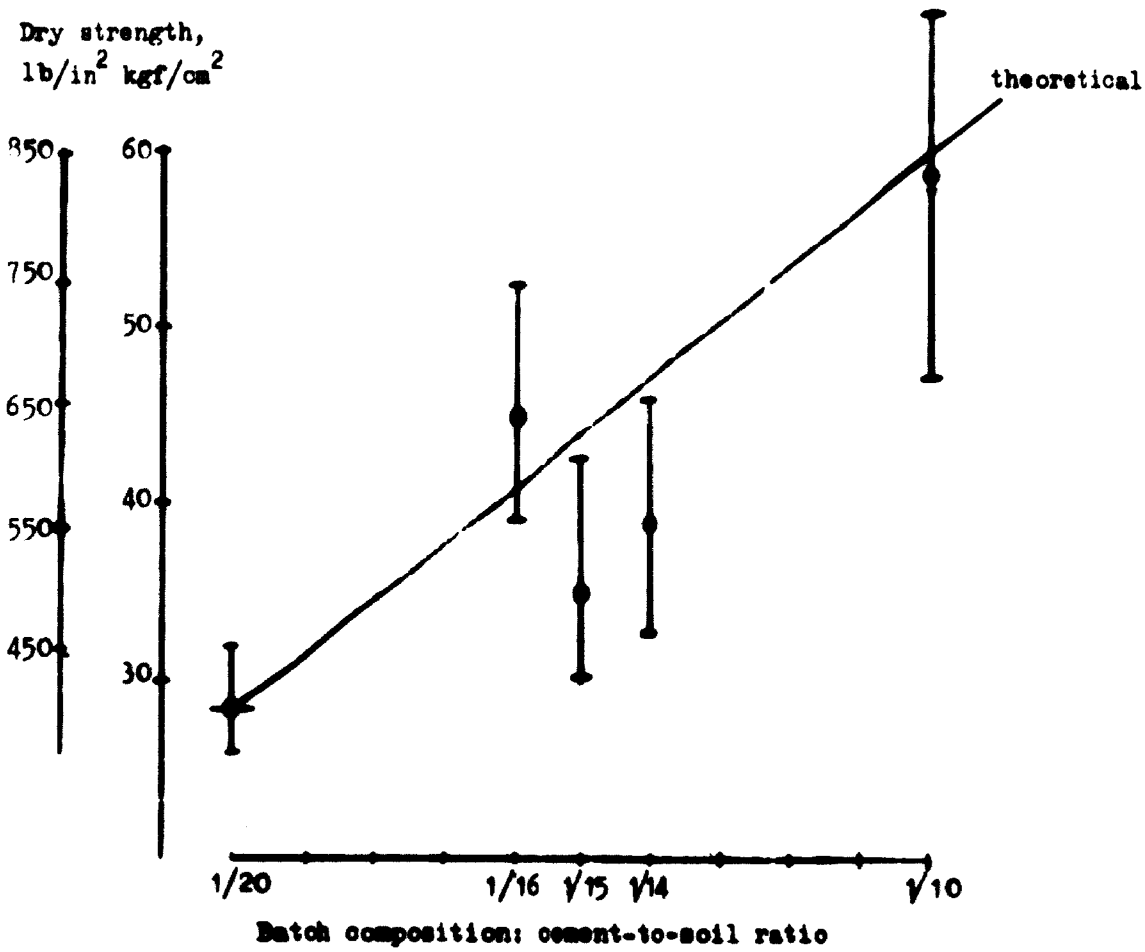

Figure I. Dependence of average dry compressive strength on batch composition of cement-stabilised soil blocks

II. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The standard of traditional housing in urbanized areas, though unsatisfactory in the long run, is reasonably good. The traditional building methods are basically sound and skills are available to improve the all-round quality of houses. As demand for improved housing is closely linked to increasing standards of living, it is anticipated that a market for better building materials will gradually develop as the country's economic situation improves.

In Malawi's state of economic development improvement in the quality of building materials may be implemented by introducing on a small scale the use of cement-stabilized soil blocks for ordinary housing and industrial building. The nature of local soils is such that cement-stabilization can be practised on a wide scale. However, due to the cost of cement and lime, soil-stabilization for the purpose of making building blocks is not a low-cost alternative to traditional building with ordinary soil blocks or even with brick.

Brickmaking is practised throughout Malawi, but the quality of bricks is variable. Along with a possible introduction of cement-stabilized soil blocks, improvement in the technology of brickmaking should be a target for further development.

Production of stabilized soil building materials on a fully mechanized industrial scale is not considered to be feasible because a ready market is not yet available. A market could be created, but it needs planning. It would need to be found first in the public sector and could gradually be extended to the private sector.

Recommendations

To make the use of cement-stabilized soil blocks in ordinary housing attractive to a would-be house-owner, incentives not related to a free market economy must be created. A recommendation in this sense can only be implemented within the framework of national housing policy and with due regard for the economic consequences of the selected way of promotion. The Minimum Building Standard Rules for Traditional Housing Areas could be the instrument to introduce better housing standards, but the financial capacity of the average plot-holder puts a limit on what can be done in this respect without adopting a subsidy system.

Subsidies could prove a useful instrument for improving quality in housing and creating market for cement-stabilized soil blocks. They could take the form of easy l. .s through official channels for traditional house-construction. Another possibility would be to employ plot-rents as a way of improving housing standards by freeing plots from rent during the first one or two years on condition that durable materials were used in accordance with adopted minimum standards. Such standards should preferably include the stipulation that at least house foundations should be of durable building materials.

A less direct way of introducing cement-stabilized soil blocks into housing construction would be to make block-presses available, either free or on hire, for private use in the traditional housing areas. (The MHC owns a number of Cinva Ram block-presses). Small-scale contractors should be able to hire or purchase block presses, possibly of local manufacture, designed to suit the size of building blocks ordinarily used.

Organized demonstrations on the employment of block presses and a distribution of pamphlets on the advantage of using durable building materials could further encourage their use by would be house-owners in the traditional housing areas.

The Government of Malawi should consider a follow-up of this preliminary study which should be directed towards two principal goals:

(a) The establishment of a National Housing and Building Materials Research Unit with the task of improving the quality of housing, promoting the gradual introduction of a range of durable building materials in ordinary housing, and acting as an official advisory body on housing policy;

(b) Improvement in the technology of brickmaking as practised around the main urban centres, making this the first priority in the gradual industrialization of building materials manufacture. Subsequently the making of non-ceramic building blocks on a semi-industrial scale could be pioneered in an area near Lilongwe.

The comparatively high initial costs of production render it highly improbable that cement-stabilized soil building materials will find a ready market even when introduced at cottage industry level. Further technical assistance should therefore focus on improvement in brickmaking skills at present practised throughout the country with variable results. The ceramic brick is already known and accepted as the durable building material for ordinary permanent housing and is produced as cheaply as, or even cheaper than, any cement-stabilized soil block.

A comprehensive study of Malawi brickmaking concentrating mainly on the quality of brickmaking and the economics of expanded brick production by use of a more advanced technology would be worthwhile.

Annex I

SOIL TESTING

The particle size distribution of a soil should ideally be such that its gravel, sand, and silt, plus clay fractions, are about equal in weight so as to obtain good compaction while making blocks and thereby good compressive strengths.

The following describes an on-the-spot test. A more sophisticated process and the determination of special parameters can only be carried out in a laboratory.

On-the-spot testing

1. Remove the topsoil, a layer of about 10 cm, over an area of roughly one square foot.

2. Loosen the earth with a spade, shovel, or hoe within that area and mix it lightly before taking a sample.

3. Take a fairly large sample, i.e., a shovelful, and pour it into a straight-walled glass jar, preferably capable of holding approximately one litre, until this is about one third full.

4. Add water to the sample in the jar to about two-thirds of its volume cover the jar, and shake vigorously until the whole sample has gone into suspension.

5. Put the jar away and allow the particles to settle. The soil settles in such a way that after a time the coarse particles are at the bottom of the jar, gradually becoming finer, with the most fine-grained fraction on top. This gradation can be observed as a stratification of the sedimented soil sample. Depending on the particle size distribution of the soil, settling may take from a few minutes to one hour or more. Remaining organic matter usually floats on top of the water.

6. After being settled for about 30 minutes the particle size distribution should be judged visually and the height of the sedimented particles measured.

7. When stratification is clearly visible, the following general rule for suitable soils should be observed: the amount of fine-grained particles should preferably be not less than one tenth and not more than half the height of the solid matter.

8. When stratification is not visible, the reason is that the soil has a very narrow range of particle sizes. This is the case with certain sands and clays. Uniformly sized sands settle down quickly, clay particles remain in suspension for a very long time.

These soil types can of course also be recognized more directly by their physical appearance.

9. Should the amount of fine-grained particles be more than one half of the total solids, the soil may still be used by adding sand or gravel to render it suitable for block making. Repeated testing after addition will show to what extent coarse-grained materials must be added.

Soils lacking a fine-grained fraction cannot be improved and should be avoided.

10. Unless the available soil is known to be uniform throughout, it is advisable to make numerous on-the-spot tests, covering the whole plot in order to ensure that all the earth within reach (also in depth) can be used for blockmaking.

Annex II

PREPARATION OF THE SOIL-CEMENT MIX AND MOULDING OF THE BLOCKS

The following is a short description as to procedures in general. Comprehensive instructions on the making of soil-stabilized blocks and their utilization are given in the publications listed at the end of this annex.

Drying

After the soil has been tested and found suitable for blockmaking, the earth excavated from the latrine pits and the foundations can be used for this purpose.

The soil is allowed to dry completely, i.e., if necessary, it ought to be spread out and raked.

Screening

The dry soil is screened through a 1/4-in. or 3/8-in. square mesh so as to eliminate the very coarse grit fraction.

Mixing

The screened soil is then dry-mixed with cement. For most purposes the proportion of cement to soil must on a dry weight basis be within the limits of 1 part cement to 10-15 parts dry soil.

As the moisture content and the density of dry soil and cement are approximately the same, proportional weighing can be done by volume, i.e., using buckets, when preparing batches for a limited number of blocks.

The mixing is done by hand in much the same way as cement mortar is prepared. The dry-mixing continues until the batch has a uniform greyish colour. After dry-mixing, the mix is wetted with a watering can and the batch is mixed again by shovel.

The process is repeated until the mix has the proper consistency for moulding, which can only be judged by taking a sample of the ready mix and squeezing it by hand. No water should appear and the squeezed sample should be able to be broken in two without crumbling.

Small amounts of water should be evenly sprinkled over a mix which still crumbles, that being too dry, and the batch thoroughly mixed again. A mix which is sticky and wet can only be saved by adding dry sand. The addition of dry soil will result in an heterogeneous mix. Caution should therefore be exercised when adding water in the process of batch preparation of a ready mix.

Concrete mixers of the drum type can be used for sandy soil. If the content of fines is over 25 per cent, the mixing becomes unsatisfactory and the soil tends to form lumps without cement.

The batch should be covered with plastic sheets or wet gunny sacks immediately after mixing in order to prevent evaporation and hence drying out of the mix before moulding.

<u>Moulding</u>

(a) <u>Moulding by hand</u>. The mould is placed on a slab of wood or hardboard. Ready-mix is scooped into the mould and shuttered until the whole space of the mould is completely filled. Superfluous mix is removed from the top by using a broad knife or a thin wire string. The mould is lifted and the ready-shaped block put on one side. The mould is lightly rinsed so as to be ready for use again. Soils rich in clay may have a tendency to stick to the mould. This can be avoided in two ways:

(i) The mould can be made to be hinged in one of the corners and clamped in the opposite corner when in use;

(ii) The mould can be lightly oiled when in use, with sump oil if available.

(b) <u>Moulding by block press</u>. A better compaction of the mix, giving a more solid block, can be produced by using a block press of the Cinva Ram type. Manuals describe the detailed procedure which consists of loading of the mould box, compacting the mix by applying pressure, and ejecting the finished block whereupon it is left to dry.

After moulding the blocks are set to cure, preferably on boards. The ready blocks should be set closely spaced in separate rows. After the whole batch has been moulded, all blocks should be covered with plastic sheets or wet gunny sacks, i.e., they should be cured similarly to concrete blocks.

<u>Curing</u>

The complete curing of blocks takes something over four weeks, a period during which they obtain their maximum strength. Attention must be paid to the following:

(i) The moisture content of the blocks must decrease slowly, under cover, and be protected against sun and rain;

(ii) For the first three or four days the blocks should be lightly sprinkled with water twice a day while spaced in separate rows;

(iii) The blocks should not be stacked before a week has elasped;

(iv) If necessary, blocks can after 10 days be used and be piled into a wall where they will continue to cure.

Stacking or usage neither interferes with nor prolongs curing.

Uses

(a) Blocks are used in much the same way as Kimberley blocks, bricks, or other structural building materials. In laying them, the same mortar can be applied as would normally be used. It is not advisable, though, to use mud alone as is done with Kimberley blocks. A mixture of mud and cement or lime in approximately the same proportion as used for making blocks will produce a suitable mortar.

Because blocks moulded in a press have fairly constant dimensions and a smooth surface, the joints can be made thinner and less mortar will be used than is the case with Kimberley blocks or bricks;

(b) The ready mix can be used for floors. A slab 10-20 cm thick on a well-drained, compacted sand or levelled earth filling will suffice for most purposes;

(c) When using mechanical equipment, the soil-cement mix can be used to manufacture semi-hollow blocks, half-blocks, and tiles.

The use of lime instead of cement

If lime is more readily available than cement, the same procedures for blockmaking apply. The only differences are:

(a) The added proportion should be doubled, that is, the proportion of soil to lime should be between 5:1 and 7:1;

(b) The curing time for the ready-made blocks is twice that for soil-cement blocks, i.e., 8 instead of 4 weeks.

References

Handbook for Building Homes of Earth, Department of Housing and Urban Development, Division of International Affairs, Foreign Office, Washington DC.

R. Spence, Making Soil-Cement Blocks (Lusaka, 1971).

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Annex III

TECHNICAL LIMITS FOR CEMENT-STABILIZED SOIL BLOCKS

A condensed review is given herewith of a number of technical parameters deducted from various laboratory and field tests. These are all related to the main material criterion, durability, being the soaked strength as measured according to ASTM Standard D 1559-65.

Minimum soaked strength requirement

Several researchers have established criteria and a range of strengths between 14 and 22 kgf/cm^2 have been recommended.

It is not always clear which type of blocks have been used for testing and how the blocks have been cured. It will however be advisable to establish a minimum soaked unconfined compressive strength of 17 kgf/cm^2 (240 lb/in^2) for standard blocks by adhering to the following conditions when the raw materials are tested in the laboratory:

(a) Use of standard compaction moulds;

(b) Removal of dynamically compacted specimens of required dry density (e.g. 1.90 gm/cm^3) with a moisture content of 15 per cent from the mould after approximately 15 minutes;

(c) Sealing of the specimens in plastic bags with free water available to provide 100 per cent relative humidity;

(d) Curing for 7 days at temperatures between 20° and 30°C;

(e) Soaking for 24 hours before testing.

Laboratory tests have repeatedly indicated that the soaked strength is related to the following variables:

(a) Cement content

The soaked strength of cement-stabilized soil blocks is linearly proportional to the cement content up to 15 per cent dry weight. Soil and cement mixtures beyond this limit need generally, for economic reasons, not be taken into consideration. The minimum cement content of blocks with a dry density of 1.90 gm/cm^3 shall not be less than 5 per cent dry weight (1:20) in order to meet the minimum soaked strength requirement for any soil.

(b) Dry density (as a measure of compaction)

Proportionality between the dry density of blocks and their soaked strength indicates that the minimum requirement of 17 kgf/cm^2 is reached at densities not below 1.75 gm/cm^3 for mixtures with a maximum cement content of 10 per cent.

(c) Moulding moisture content

The moulding moisture content is not specifically related to soaked strength. For practical reasons it should be kept between 10 and 15 per cent.

(d) Lump size and content of fines

The soaked strength of blocks is slightly influenced by the maximum lump size in the available soil. The maximum lump size should preferably be 10 mm (3/8 in.). Diminishing maximum size increases the soaked strength by a factor varying from 1.2 to 1.5 between 10 mm and 2 mm. The influence of the content of fines is best illustrated by a graph representation of its effect on soaked strength as shown in figure II.

(e) Curing time and curing conditions

Maximum soaked strength of cement-stabilized soil blocks is only obtained after a curing period of at least 30 days. After about 15 days the blocks can be transported or even used for building purposes.

A very important variable affecting the soaked strength is the degree of curing care, as generalized in figure III.

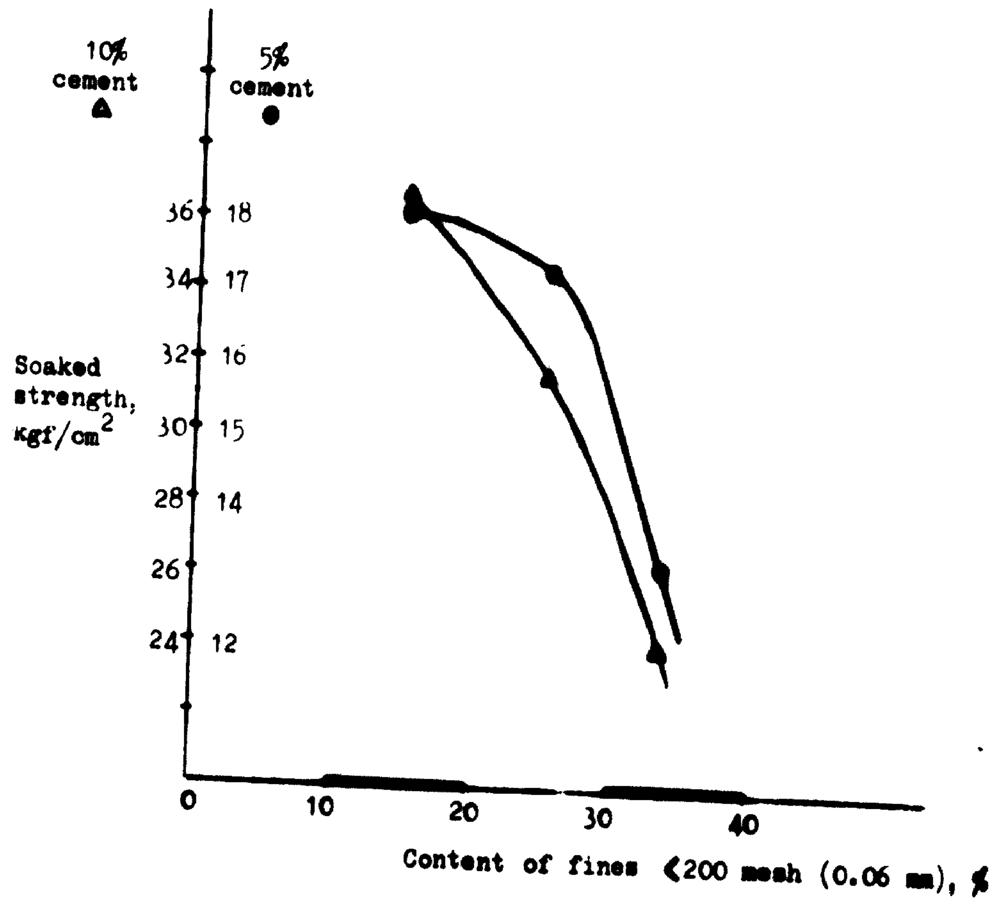
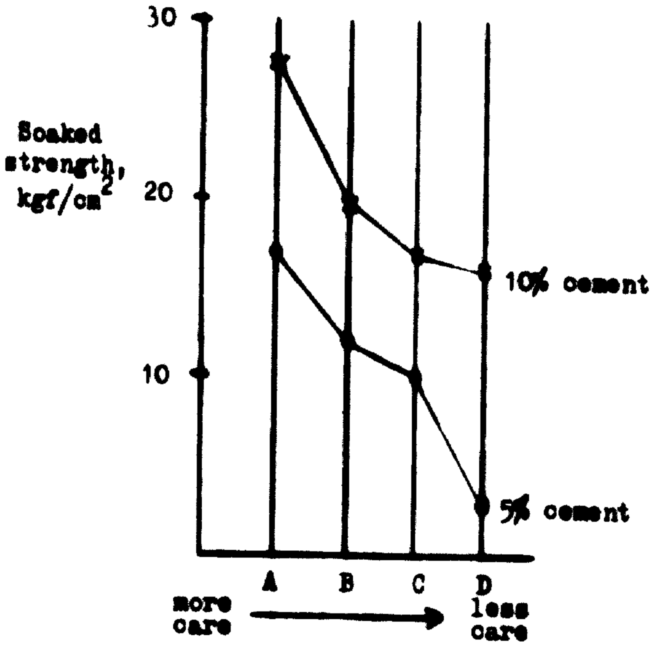


Figure II. Dependence of the soaked strength of cement-stabilised soil blocks on the fines content of the soil



A = cured at 100% relative humidity
B = cured inside (covered with plastic sheet)
C = cured outdoors in shade
D = dried in the open

Figure III. Soaked strength of blocks as related to amount of care used in curing them

Annex IV

SOIL PARAMETERS

Location	Sample No.	Percentage Passing Screens: 1.5	1.00	3/4	1/2	3/8	3/16	7	36	52	100	200	% fines visual	Liquid Limit	Plasticity Index	Shrinkage	Classification
South Lunzu	1						100	99.3	87.3	78.3	50.9	36.3	43	12.3	6.4	2.0	A 4 (0)
	2						100	99.5	89.5	83.8	65.4	50.9	54	27.8	10.6	5.3	A 6 (4)
	3					100	93.1	88.1	72.3	65.8	84.2	54.9	47	24.6	10.9	4.0	A 6 (5)
	4				100	87.8	80.2	74.1	47.8	39.8	25.6	18.7	27	Slightly plastic		0.[illegible]	A1-6 (0)
	5						100	99.7	88.9	84.6	69.9	56.5	36	35.9	15.3	8.0	A 6 (6)
	6					100	94	88	55.3	48.9	35	24.3	21	Non-plastic		0	A2-4 (0)
	7				100	97.9	90.7	83.6	56.7	52.1	41.8	24.1	34	27.3	12.6	6.0	A2-6 (0)
	8						100	98.1	81.9	75.3	56.3	44.2	nd	34.3	13.4	6.7	A 6 (3)
Zomba	1					100	95.7	94.1	78.9	74.4	62.1	53.3	60	30.4	11.6	6.0	A 6 (5)
	2					100	99.1	96.1	78.1	73.3	59.7	51.3	64	30.8	13.5	6.7	A 6 (4)
	3						100	99.3	67.3	59.5	43.3	33.4	31	23.1	9.1	4.0	A2-4 (0)
	4						100	97.8	76.5	71.1	57.9	50.4	54	29.3	10.4	4.0	A 4 (3)
	5						100	98.6	79.2	73.6	59.6	57.3	57	30.9	12.8	6.0	A 6 (5)
	6				100	97	95.6	93.1	66	58.7	43.1	36.6	58	33.1	12.7	4.7	A 6 (1)
Mlanje	1							100	86.4	82.2	71.7	65.9	57	51.7	26.2	12.1	A7-6 (14)
	2						100	99.6	72.8	63.3	54.1	45.7	49	32.9	14.9	7.4	A 6 (4)
	3						100	97.3	59.6	47.6	23.2	14.5	0	Non-plastic		0	A2-4 (0)

Annex IV continued

Location	Sample No.	Percentage Passing Screens 1.5	1.00	¾	½	⅜	3/16	7	36	52	100	200	% fines visual	Liquid Limit	Plasticity Index	Shrinkage	Classification
Chombeze	23/1						100	98.0	79.3	75.0	66.1	59.6	56	27.3	8.7	4.7	A 4 (5)
	23/2						100	98.3	80.7	74.7	60.8	50.1	34	30.8	10.9	4.4	A 6 (4)
Balaka	1						100	99.5	84.6	79.5	66.5	58.3	56	39.3	16.1	8.7	A 6 (7)
	2						100	99.4	81.6	77.6	66.4	57.0	63	37.6	16.0	8.0	A 6 (6)
Mwenye							100	97.1	75.0	65.8	46.9	35.1	21	Non-plastic		0	A 2-4 (0)
Lilongwe	1						100	99.2	79.0	68.1	49.0	36.6	nd	26.4	11.4	4.7	A 6 (0)
	2						100	96.4	66.6	58.4	39.9	27.7	nd	27.8	12.4	4.7	A 2-6 (0)
Salima	1						100	99.1	58.7	46.1	26.4	18.2	12	Slightly plastic		1.3	A 2-4 (0)
	2							100	59.3	46.4	24.9	16.7	13	Non-plastic		0	A 2-4 (0)
	3						100	96.2	76.7	67.6	48.7	37.8	48	26.9	10.9	4.7	A 6 (0)
	4						100	99.6	92.6	82.6	60.8	47.1	56	Slightly plastic		1.4	A 4 (2)
	5						100	98.3	76.3	70.1	56.9	48.0	60	32.7	17.0	7.3	A 6 (4)

Annex IV continued

Location	Sample No.	Percentage Passing Screens 1.5	1.00	3/4	1/2	3/8	3/16	7	36	52	100	200	% fines visual	Liquid Limit	Plasticity Index	Shrinkage	Classification
Chintheche	1					100	91.5	88.7	80.2	75.1	59.3	45.2	nd	26.[illegible]	[illegible]	[illegible]	A [illegible]
	2						100	94.9	84.7	[illegible]	56.8	[illegible]	nd	28.[illegible]	[illegible]	4.7	A [illegible] (2)
	3		100	93.4	91.2	90.2	86.1	82.8	74.7	70.0	55.6	46.8	nd	42.1	19.2	8.0	A 7-6 (5)
	4							100	50.7	36.7	11.7	6.6	nd	Non-plastic		0	A 3 (0)
[illegible]	1						100	99.7	64.1	52.6	35.4	28.0	[illegible]	26.[illegible]	10.[illegible]	4.7	A 2-6 (0)
	2						100	99.6	75.1	64.2	42.2	38.7	20	2[illegible].6	11.6	5.3	A 6 (1)
	3							100	64.3	51.1	26.4	18.6	[illegible]	Non-plastic		1.3	A 2-4 (0)
	4						100	99.6	60.6	47.3	29.8	23.5	17	22.7	9.6	3.3	A 2-4 (0)
Karonga	1						100	99.2	83.2	73.9	51.3	33.8	56	Slightly plastic		1.4	A 2-4 (0)
	2							100	97.1	92.8	72.0	54.1	61	3[illegible].8	16.7	7.4	A 6 (10)
	3							100	97.1	96.1	91.8	84.8	nd	42.5	19.5	7.3	A 7-6 (12)
	4						100	99.2	96.5	95.5	91.0	83.6	nd	41.3	16.4	7.3	A 7-6 (10)
	5						100	99.5	97.4	96.7	93.5	87.4	nd	41.1	18.2	8.0	A 7-6 (11)
	6						100	98.8	96.4	95.4	92.1	87.3	nd	43.4	18.2	8.0	A 7-6 (12)
	7						100	98.6	63.6	48.6	31.6	27.6	15	21.6	4.9	1.3	A 2-4 (0)

Annex V

SHORT DESCRIPTION OF SOIL SAMPLES FROM THE AREAS TO BE ALLOCATED TO TRADITIONAL HOUSING SCHEMES

Location	Sample number	Description
South Lunsu	1	black earth, rather sandy
	2	grey soil, sticky when wet
	3	grey soil
	4	coarse-grained grey soil, near rock outcrop
	5	red soil, sticky when wet
	6	black soil, sandy
	7	sandy gravel, used also for road construction
	8	black sandy soil
Mtenje	1	red soil, rather fat
	2	red-brown sandy soil
	3	grey clayey sand
Mwenye	1	rather sandy clay, used for brick-making
Chombeze	1	fatty sandy clay, used for brick-making
	2	fatty sandy clay, used for brick-making
Zomba	1	red-brown soil, rather plastic when wet
	2	red-brown soil
	3	sandy grey clay
	4	brown soil
	5	red-brown sticky soil
	6	dark-grey soil, between rock outcrops
Balaka	1	rather stiff black soil
	2	stiff grey-brown clayey soil

Location	Sample number	Description
Lilongwe	1	red-brown sandy soil, used for making cement-stabilized blocks
	2	greyish soil with organic matter, used for making cement-stabilized blocks
Salima	1	black sandy earth
	2	sandy black soil
	3	stiff sandy soil, black
	4	sandy brown soil
	5	grey soil, rather stiff
[illegible]	1	red lateritic soil with pebbles
	2	red soil
	3	red soil with many pebbles
	4	grey sand
Mzuzu	1	sandy red-brown soil
	2	sandy red soil, rather stiff
	3	dark-grey "dambo" sand
	4	yellow-grey sandy soil
Karonga	1	grey sandy soil
	2	brown sandy soil, rather stiff
	3	stiff grey-brown soil, water level 1.2 m below surface
	4	rather stiff dark-grey soil
	5	stiff dark-grey soil
	6	stiff dark-grey soil
	7	dark-grey sandy soil
Ngabu	1	dark-grey clay, rather stiff, waterlogged

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