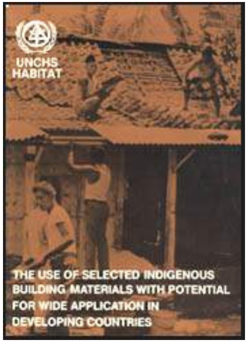

The Use of Selected Indigenous Building Materials with Potential for Wide Application in Developing Countries (HABITAT, 1985, 80 p.)

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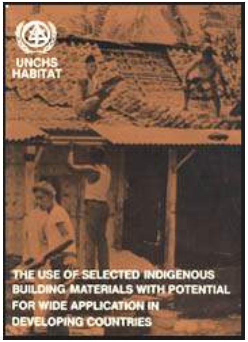
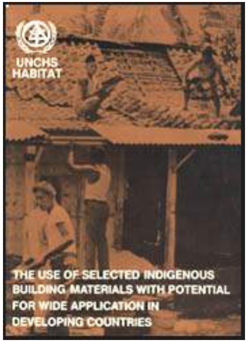


UNCHS
HABITAT

United Nations Centre for Human Settlements (Habitat)
Nairobi 1985

HS/83/85/E
ISBN 92-1-131007-5



The Use of Selected Indigenous Building Materials with Potential for Wide Application in Developing Countries (HABITAT, 1985, 80 p.)

FOREWORD

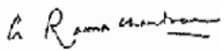
The high cost and insufficient supply of building materials in developing countries is partly a consequence of the dependence on imports. The United Nations Centre for Human Settlements (Habitat) has, for a long time, been dealing with the subject of promoting the building materials sector, on principles of import-substitution and self-sufficiency. In general, this calls for a rapid expansion in production of indigenous building materials. Most countries possess the basic inputs required for production of an array of indigenous building materials: raw materials, labour, basic tools and energy. However, these potentials are yet to be translated into actual commercial-scale

production. In several countries, some indigenous materials are being produced but not in sufficient quantities and sometimes at costs which are not competitive with imported materials.

While there are opportunities to promote the wide-scale use of indigenous building materials, this can only be realized if certain constraints are eliminated through the adoption of a specific set of measures. This report examines the factors which act as constraints to the production and use of indigenous building materials and identifies measures which can be undertaken to overcome the constraints.

With regard to shelter delivery for the low-income population, accessibility to basic building materials in sufficient quantities and at affordable costs is of key importance and one of the most dominant issues to be tackled. This report, therefore, fulfils one of the goals of the International Year of Shelter for the Homeless by providing decision-makers in developing countries a basis on which to undertake reforms in the building materials sector.

I hope that the measures identified in this report as well as the illustrations of successful country case studies in the field of indigenous building materials production, will be useful in providing a framework for governments to attain local capacity in fulfilling the demands of the low income population for building materials.



Dr. Arcot Ramachandran
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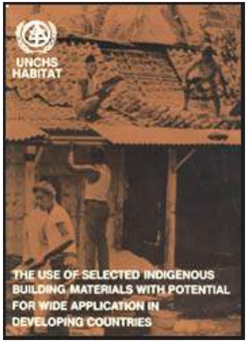

INTRODUCTION

Promoting the building materials sector in developing countries has been a subject of importance to the United Nations as far back as Habitat: United Nations Conference on Human Settlements, held at Vancouver in 1976. The subject has been given considerable attention in the activities of UNCHS (Habitat) since its inception, and, in recent times, it has been repeatedly highlighted as one of the most pressing areas of concern in human

settlements development. For instance, in March 1985, UNCHS (Habitat) and the United Nations Industrial Development Organization (UNIDO) jointly organized the First Consultation on the Building Materials Industry,[1/] for the purpose of fostering collaboration between industrialized and developing countries, thus leading to improvements in the building materials sector in developing countries.

[1/] First Consultation on the Building Materials Industry, Athens, 26-30 March 1985.

The main reason building materials continue to receive priority attention is that they are the main input in the construction of houses, schools, factories, airports, roads, water supply facilities, dams and, indeed, the whole multitude of items which absorb the main investments in human settlements. However, building materials have been a cause of inadequate construction output, high construction cost, abandonment of construction projects and, sometimes, inadequate building maintenance in developing countries. This situation has come about because, in most cases, basic building materials are obtained from predominantly imported sources using scarce foreign exchange, so that costs are prohibitive and supply is limited.

To a large extent, the trend of rising costs and falling supplies of materials can be reversed, if the system of production is based on locally available resources. Indigenous building materials exist but are either unpopular because of their low quality or simply insufficient in supply. In most countries, efforts are being made to promote the use of indigenous building materials, and these have led, on the one hand, to improved traditional materials and, on the other, development of relatively innovative materials. However, despite the potential for their wide application in developing countries and despite increased efforts to promote their production, most indigenous building materials have not made tangible impacts on the construction market. The purpose of

this report is to assess the importance of the indigenous building materials sector in developing countries and to outline the constraints which limit the wide-scale adoption of indigenous building materials and to indicate some possible measures that decision-makers and related professionals can take to resolve the issue.

What constitutes an indigenous building material will vary from one country to the next, but the basic criteria will be applicable to most countries. For this reason, this report deals with the production and use of indigenous building materials on the basis of commonly accepted principles and concepts, rather than by relevance to a comprehensive range of specific materials. However, a few building materials have been selected to illustrate the broad issues related to the promotion of indigenous building materials. The examples are limited to low-cost cementitious materials.

The report is made up of five chapters. Chapter I presents an overview of the building materials situation in developing countries, reviewing the importance to national development of the construction sector and the main obstacles to improving its efficiency. Chapter II addresses the question of what constitutes an indigenous building material, with a view to determining criteria which will be applicable to most developing economies. Constraints which limit the adoption of indigenous building materials are discussed in chapter III, while chapter IV suggests measures to promote the wide-scale adoption of indigenous building materials. Finally, chapter V describes pertinent aspects of the production and use of indigenous building materials, using selected materials as an illustration.

A review of production of indigenous cementitious materials in selected countries is provided in annex I. Incidentally, these selected materials, if successfully promoted, are likely to lead to improvements in the building materials situation of the low-income population because the factor inputs for their production are widely available at affordable costs and, moreover, they can satisfy the bulk of the requirements for low-

income shelter.

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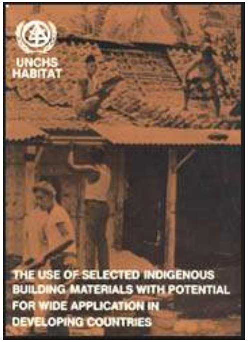

The Use of Selected Indigenous Building Materials with Potential for Wide Application in Developing Countries (HABITAT, 1985, 80 p.)

I. AN OVERVIEW OF THE BUILDING MATERIALS SECTOR IN DEVELOPING COUNTRIES

A. Importance to national development

1. Economic growth is directly related to the level and efficiency of capital formation. In developing countries, construction of roads, railways, harbours, factories, dams and a multitude of buildings and physical infrastructure installations absorbs most investment in human settlements, accounting for about 80 per cent of total capital assets. These investments are a prerequisite for the functioning of almost all other sectors of the

economy, and because they produce fixed assets, a single investment yields continuous benefits over a long period. Investments in low-income shelter are, similarly, significant to national development, even though they are often ignored or not accounted for. In most urban slums, squatter settlements and rural areas, construction of shelter provides both a living place and a working place for the production of goods and services which are vital to the development process.

2. Typical indicators of underdevelopment are inadequacies in physical infrastructure, shelter and related amenities. The responsibility for improving this situation rests, to a large extent, on the ability of the construction industry to meet the demands for basic physical investments in the built environment. Given this pivotal role of construction in national development, the building materials constitute the single largest input in construction. About 50 per cent of the total cost of all construction can be accounted for by building materials alone, and, in low-income shelter, the value of building materials could be as high as 8O per cent of total cost because of the relatively low requirements for other inputs, such as equipment, installations and specialized skills. In fact, in low-income construction programmes based on principles of community participation or self-help construction, building materials can at times become the only item of cost.

B. Trends in the sector

3. The building materials sector can be divided into three production groups. First, there are building materials which are relatively modern or based on modern conventional production methods. These materials, frequently called "modern" or conventional building materials, include such materials as brick, concrete, steel and glass. In most countries these materials are either produced at the domestic level, often using imported inputs, or directly imported as finished products. These materials are frequently prohibitive in cost, scarce or intermittent in supply, but, sometimes, although not appropriate, they are popular in demand, to the extent that they are the only items used

for construction. Despite scarcities, developing countries collectively performed fairly well in the production of building materials during the period 1971 to 1981.[2/] For instance, in 1981, 34.5 per cent of the world's cement was produced in the developing countries. However, on the whole, the rate of consumption of building materials is higher than the rate of local supply.

2/ UNIDO, "The building materials industry in developing countries", Sectoral Studies Series, No. 16 (Vienna, 1985), p. 17.

4. The second group of building materials can be classified as traditional. This group includes such materials as earth, stone, bamboo and thatch. These are often produced with rudimentary technologies in small scale and are sometimes characterized by low-quality performances. Although traditional building materials have been the predominant type used in the construction of shelter in low-income settlements, they are not truly popular in demand.

5. The third category of building materials can be termed "innovative". These materials represent efforts to improve the low quality of traditional building materials through research and development efforts aimed at providing alternatives to import-based materials. In some countries, innovative materials such as stabilized earth blocks or pozzolanas, have been produced only up to the level of research outputs, while in many other countries successful research findings have led only to limited commercial-scale production, so that innovative materials have not had the desired impact on the building materials market.

C. Problems of the sector

6. The main problems of the sector are that the basic building materials which are predominantly used in construction are not available in sufficient quantities and,

sometimes, are not available at all. When available, they are extremely expensive. The consequence is that vital construction projects remain incomplete or are abandoned, or, when they are completed, are excessively costly.

7. This precarious situation has come about because basic building materials are so often imported using scarce foreign exchange. The domestic production of most building materials is still based on imported inputs and technologies which tend to be large-scale, capital-intensive and urban-centered. In conventional thinking, large-scale building materials production units have the advantage of economies in cost-per-unit output, but, in most developing countries, the scarcity of production factors makes large-scale units operate far below installed capacities, thus resulting in gross diseconomies and high costs at the point of production. In addition, costs of transporting and distributing building materials from the urban centres to the rural hinterlands are excessive, because of the scarcity or high cost of fuel and the underdeveloped state of the transport network.

8. In some countries, there are hardly any alternatives to expensive conventional "modern" building materials, so that the low-income population is at a particularly disadvantage in meeting its construction requirements. It is likely that investments by the private sector in low-income shelter are being withheld or diverted until such time as basic building materials become less expensive. The expensive conventional building materials have also negative impacts on low-income shelter programmes. There are, for instance, examples of rapid increases in the price of cement leading to cost overruns and, therefore, to an increase in minimum-income requirements for project beneficiaries, thus depriving the low-income population of access to shelter.

9. Probably, the greatest problem of the building materials sector is its inability to benefit from opportunities to expand the output of the sector, using a vast array of underutilized indigenous resource inputs. In most countries, there are many locally

available resources yet to be exploited, including small-scale raw-material deposits, agricultural residues, industrial wastes, low-cost and renewable sources of energy, unskilled and semi-skilled labour and, above all, established technologies which can readily be applied to the local production of low-cost materials. In fact, there is evidence of many useful research findings on low-cost building materials at both the domestic and international levels, but there is still a wide gap between experimental innovations and their wide-scale adoption in construction.

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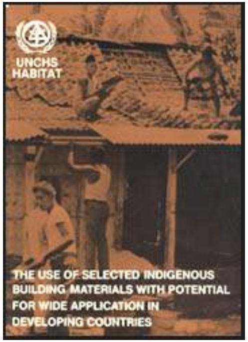

The Use of Selected Indigenous Building Materials with Potential for Wide Application in Developing Countries (HABITAT, 1985, 80 p.)

II. THE CONCEPT OF INDIGENOUS BUILDING MATERIALS

A. Variations in national resource capacities

10. If an indigenous building material is defined in such terms as a material produced within the resource limitations of a country for use in construction, then, exactly what constitutes an indigenous building material will vary from one country to the next owing to the marked differences in resource capacities of individual countries. Although developing countries tend to have several things in common, they differ in terms of available raw materials and their level of technological advancement. For this reason, one type of building material may be easily produced in one country, while in another there may be no capacity for producing the same material. Even within a country, raw material resources are likely to vary from one area to another, so that the definition of an indigenous building material may not be standard within that country. For instance, building stone is a good walling material but it is not available in many countries, so that it can only be promoted as an indigenous construction material in limited cases.

11. The availability of the main production inputs is a useful basis for promoting an indigenous building material, but it is also necessary to take account of the factors which determine the use of the material in construction. The factors which determine the suitability of building materials for construction, notably climatic factors, are not usually the same for any two countries and, often, they vary even within the same country. For instance, the widespread availability of timber in a country may establish a basis for promoting that material as an indigenous building material, but acceptance will also depend on favourable climatic conditions to minimize the threat of bio-degradation of the material. Similarly, in some parts of a country, with low rainfall or a relatively dry climate and good soils, the use of soil in construction could be a feasible indigenous building material.

12. The extent to which countries vary in their technological capacity is probably more important than the extent of variation in their natural resource endowments for the

production of building materials. In developing countries with relatively advanced technological capabilities, most primary raw materials can easily be promoted as indigenous building materials. However, in the majority of countries, skills are inadequate, and appropriate technologies are barely accessible, so that available raw materials suitable for use in construction can only be transformed into building materials by relying on imported skills and technologies. For this reason, the main factor which influence the definition of indigenous building materials could be the level of technology.

B. Indigenous building materials in the context of low-income shelter

13. As stated previously, the definition of an indigenous building material has universal application, but, in the context of the low-income population, such a definition will have to be based on building materials which are both accessible and affordable. Again, for the low-income population, the concept of an indigenous building material should be interpreted in terms of basic requirements in construction. Using shelter as an example, emphasis should be placed on those materials which will have the greatest impact in terms of construction costs. For example, materials for fittings and finishes will normally constitute a low proportion of the total cost of construction, while materials for walling and roof cladding will tend to be dominant elements in the total cost of the structure.

14. On this basis, the concept of an indigenous building material will be guided by three interrelated principles: (a) use of locally available factor inputs; (b) affordability by the low-income population; and (c) orientation to the construction needs of the majority of the population.

C. Factors of production for indigenous building materials

15. In the building materials sector, the main factors of production are raw materials, labour, machinery and energy. The relative importance of each factor of production will

depend, to a large extent, on the type of building material to be produced. However, it is desirable that all the factors of production be available at the local level in order to achieve the objectives of indigenous production. As explained below, each factor input is vital to the production process and, if ignored, could be the single cause for defeating the overall objective of indigenization.

1. Raw materials

16. The raw materials that a country possesses are the basic determinants of the type of building materials that the country can produce. In fact, certain raw materials, such as soils and building stone, in their natural state and without undergoing any production process, can be used as building materials. However, in general, raw materials serve as an input to production, either as a primary or secondary input. Raw materials can be classified as primary where they provide the main or only raw material in the production cycle.

17. For example, the primary raw material required for production of fired-clay bricks is clay, while the primary raw material required for production of lime is limestone. The production of composite materials, such as concrete blocks, asbestos-cement roofing sheets or fibre-cement roofing sheets, requires a combination of two or more raw materials, but, nonetheless, such secondary raw materials are as vital as the primary raw material, because deficiency in a single item leads to unsatisfactory production. For most building materials, the raw materials constitute the bulk of the final product, and the low value-to-weight ratio attributed to building materials is mainly due to the weight of the raw materials. For these reasons, the entire purpose of promoting an indigenous building material may be defeated if the raw materials have to be imported. Similarly, if the raw materials have to be transported over long distance within a country, the objective of low-cost production may not be realized.

18. In the production of certain building materials, such as lime, pozzolanas and panel boards, raw materials are interchangeable. The substitutability of one raw material for another, to produce the same standard product, is useful in promoting indigenous building materials. By implication, varying resource endowments in different parts of a country may be used to produce one type of building material, so that the burden of transporting raw materials over long distances is minimized.

2. Labour

19. Skilled and unskilled labour is essential for the production of most building materials. In the building materials sector, skills are required to identify the types of indigenous raw materials which can be used to produce a variety of building materials. In addition, skills are required in the pre-production and production stages, some of which are complex and intricate.

20. For example, in the production of fired-clay bricks, skills are required in mining the clay, mixing and moulding the clay, stacking and drying the green bricks and firing the green bricks to obtain the final product. There are several labour-intensive techniques for production of building materials, and they are particularly suited to the situation in most developing countries where there is surplus labour coexisting with scarcity of capital. However, even the most labour-intensive building materials operation requires some basic skills. A material as simple as sun-dried earth blocks, which are frequently produced on a self-help basis as a peasant product, still requires some skills in identifying the appropriate soil mix and in moulding and curing the blocks. In fact, the unsatisfactory state of most earth buildings in rural areas is primarily due to the lack of skills on the part of those who use the material.

21. Apart from promoting quality of output, skills are required to minimize the cost of production and, at the same time, increase the quantity of output. This will require that

the available local labour force be trained in appropriate production and management techniques. Perhaps, the best illustration of the importance of labour as a determining factor in a viable indigenous building materials industry is the fact that labour can substitute for capital in certain types of production and, where machinery is essential, that installed machinery can be maintained directly on the production line.

3. Capital

22. Capital inputs, notably machinery and equipment, are sometimes indispensable for the production of a variety of building materials. Modern and conventional materials, such as cement, steel, glass and some timber components, can hardly be produced without the intensive use of capital items. In some instances, the demands for capital items are limited to simple tools, such as moulding tables, steel fabricated moulds, wheel-barrows and pick-axes, but these are indispensable to the production cycle.

23. In most developing countries, capital is scarce and expensive, but basic machinery and equipment are often imported with limited foreign exchange, and their operation and maintenance is dependent on imported inputs. Yet, for most indigenous building materials, cost of production can be minimized, quality of products improved and output expanded, if appropriate technologies are applied. In some instances, the main requirements for production are constructed facilities, such as warehouses and factories. Nevertheless with an underdeveloped local capital market, even minimal investments in building materials production can hardly be generated.

4. Energy

24. Energy is a crucial factor in the production of a variety of building materials. For materials such as clay bricks, tiles, gypsum and lime, energy is essential to transform the raw material into the final product. For this reason, energy must be available to promote

an indigenous building materials industry.

25. Some production technologies are only suited to expensive and scarce sources of energy, while others are suited to low-cost and renewable forms of energy. Energy alone accounts for over 50 per cent of the production cost of energy-intensive building materials, such as bricks, lime and cement, so that, in situations where such energy has to be imported, the result is a prohibitive cost of the final product. Again, where energy has to be imported, it is likely that the supplies may not be regular, so that production becomes intermittent and output falls below installed capacity, thereby raising the final production cost. Some agricultural residues are good sources of energy for building materials production, but it is desirable that they be available in quantities sufficient to support the production cycle beyond the post-harvest period of farming and that, in addition, these sources of energy should be in proximity to building materials production sites, so as to minimize the cost of transport.

D. Scale of production

26. In the building materials sector, the scale of production determines the production factors to be used and these, in turn, influence the cost of production. For this reason, the promotion of an indigenous building materials industry depends on the appropriate scale of production being adopted. In most developing countries, large-scale units operate far below installed capacities, with gross diseconomies and high costs at the point of production. However, in contrast to large-scale systems, small-scale building materials production units are capable of functioning within the available resources of developing countries.[3/]

3/ UNCHS (Habitat), "The small-scale production of building materials" (HS/C/9/5) (Nairobi, 1985).

27. In most countries, there are abundant small deposits of raw materials, often of an inferior quality but, nonetheless, suited to small-scale technologies for the production of building materials. The suitability of small-scale technologies is also enhanced by their ability to use a multitude of industrial and agricultural wastes in the production of building materials. Most small-scale building materials production units are labour-intensive, so that they fit in well with the abundance of labour in most developing countries, and, in small-scale operations, building materials can be produced with low investment in capital items and low foreign-exchange content. Fuels on which small-scale technologies can operate include a multitude of residual products, most of which are renewable and occur as waste products.

28. Because of the low value-to-weight ratio of building materials, the cost of transport and distribution is also important. In most developing countries, the transport of building materials from production points to construction sites involves covering long distances in situations where fuel is scarce of expensive and the transport infrastructure underdeveloped. In some developing countries, the cost of transporting building materials exceeds the production cost, so that an indigenous building materials production programme should be based on the limitations of the transport infrastructure. Small-scale plants have the advantage of being able to locate close to market points, so that the final product does not have to be transported over long distances.

29. If indigenous building materials are to lead to improvements in supply and cost of basic items, one important criterion is for systems which can be brought on to the production line in the shortest possible time. Large-scale production systems normally require a relatively long period for installation. For instance, large-scale plants for cement production can only be brought on to the production line in four to six years, compared to a mini-plant for cement manufacture which can be brought on to the production line in about one year. In fact, some basic small-scale technologies for a variety of building materials require the bare minimum time to be installed.

E. The use of materials in construction

30. Building materials are predominantly produced to serve the construction sector, so that the primary task in promoting an indigenous product is to ensure that the material can readily be applied in construction. Thus, an important factor which determines the success of an indigenous building material is the availability of the requisite skills to use the material in construction. For instance, even though fired-clay roofing tiles are potentially indigenous materials, their use is dependent on a supply of trained artisans who can lay the tiles in a variety of circumstances. In most countries, there are popular and traditionally accepted construction skills and techniques, and it is important to ensure that the introduction of an indigenous building material is consistent with established construction practices. By illustration, the skills and techniques involved in laying roofing sheets are entirely different from those required for laying roofing tiles, so that, on the basis of available skills, these differences should be of primary concern in deciding what indigenous roofing material to produce.

31. Construction skills are important to the extent that they can improve the durability of low-quality building materials. Conversely, where skills are inadequate or deficient, good quality and durable materials can be wrongly used in construction, thereby making an indigenous building material unattractive. Indigenous building materials might be cheap to produce, but, if appropriate construction skills and techniques are not available at the point of using the materials, there is always a likelihood that there will be wastage and inefficiency in construction, leading to an unnecessarily expensive output in construction.

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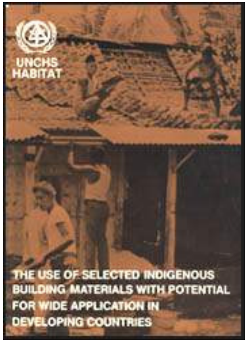
The Use of Selected Indigenous Building Materials with Potential



The Use of Selected Indigenous Building Materials with Potential for Wide Application in Developing Countries (HABITAT, 1985, 80 p.)

III. CONSTRAINTS LIMITING THE ADOPTION OF INDIGENOUS BUILDING MATERIALS

32. Despite the favourable factors for promoting indigenous materials, there are some constraints which limit the widespread production and use of such materials. In some countries, the problem is related to inadequate production capacity or the low level of demand for indigenous building materials, but, in other countries, the problem is that there is hardly any available local experience of the production and use of such materials. However, there are some constraints which are basic to most developing countries and are responsible for the inability of indigenous materials to make an impact on the building materials industry. These constraints are related to, at least, five issues, namely: (a) technology of production; (b) investment requirements; (c) quality of output; (d) demand for indigenous products; and (e) inappropriate use of materials in construction.

A. Technology of production

33. A prerequisite for commercial production of indigenous building materials is that the technologies involved be tested, proved and, above all, widely known at the local level. Although there is an international flow of information on some innovative technologies, this has not developed to the level where such technologies can readily be replicated from one country to the next. In fact, it can be argued that, although the technologies in question are not completely new, there are not many organizations which have established themselves internationally as technology suppliers in the field of indigenous materials. In India, for example, the Cement Research Institute has been responsible for developing and licensing both rice-husk-ash-cement plants and mini-plants for cement production, while the Khadi and Village Industries Commission has been active in establishing lime and lime-pozzolana production units. Outside India, there are not many known organizations with comparable experience on promotion of technologies for low-cost binders at the local level.

34. Even if an information flow on innovative technologies is achieved, the process of actual development and commercialization of a newly introduced technology is complex and resource-consuming. This acts as a deterrent to promotion of innovative technologies. The transfer of technologies from one country to another is often facilitated if the new technology is similar to locally available production techniques. However, in some cases, a country receiving an innovative technology has to devote resources to training in a variety of skills, to building physical infrastructure, to undertaking extensive demonstration programmes, and to purchasing tools and equipment. In many developing countries, the government may not be able to afford this cost of technology transfer, and, in the absence of governmental support, there is hardly any alternative means at the local level of covering the initial cost of technology transfer and development.

35. In some countries, the main factor limiting the flow of technology is not so much

related to defects in the transfer of technology at the international level but, rather, related to the inability of local institutions to translate successful research findings in appropriate technology to commercial-scale operation and to the use of the self-help builders. There are cases where technologies for production of low-cost materials have been developed by a local agency based on indigenous factor inputs, yet these findings have not been demonstrated on an extensive scale or replicated by any other agency.

B. Investment requirements

36. When an innovative technology has finally been transferred from one country to another, the task of commercial-scale adoption of the new technology in the recipient country depends largely on how some basic constraints to investments for building materials production are tackled. For instance, access to raw materials could be a serious factor inhibiting local investment in indigenous building materials production. Most of the technologies for production of low-cost materials are appropriate at the small scale, with the advantage that they can utilize small deposits of raw materials for their operations, yet it is precisely the small deposits or of raw materials which are often neglected in most countries. Information on small-scale deposits of raw materials, such as clay, limestone and gypsum, is hardly available at any local agency. An investor would typically like to have full knowledge of raw-materials deposits, in terms of the quantity available and the suitability of the material for production. This often involves extensive pre-production tests which are costly, and normally a small-scale entrepreneur would avoid such pre-investment costs.

37. The inaccessibility of raw materials could be due to the lack of access roads to the source of raw materials, and, again, the high cost of providing such basic infrastructure could deter local entrepreneurs from investing in the indigenous building materials sector. Sometimes, an access road to the source of the raw materials may be available, but a suitable site for locating the production plant may be too far away from the source.

For example, the lime-pozzolana industry in Rwanda exploits limestone deposits from a source five kilometres away from the factory, while the pozzolana is derived from a volcanic ash cone located about 40 kilometres from the production plant. In most countries where the transport infrastructure is underdeveloped and fuel costs are high, the distant location of basic inputs for production may easily frustrate efforts in promoting wide-scale production of indigenous building materials.

38. The use of agricultural residues, such as rice husk for production of pozzolanas and coffee husk as a source of fuel in building materials production, is an important innovation which can have an impact on cost reduction of local building materials. However, the cyclical nature in which they become available can pose a limitation to the production process. If such agricultural products are to be used in the production process, it is desirable they be available throughout the entire duration of the building materials production cycle which may extend far beyond the period when farmers harvest their agricultural produce.

39. For this reason, an investor may have to purchase large quantities of the agricultural residues at the time they are available and hold them in stock. A small-scale investor will require credit for working capital, in order to ensure a planned output. In most developing countries, there are hardly any effective credit facilities for small-scale entrepreneurs.

40. The overall capital requirements for the production of most indigenous building materials are relatively low and can often be met within the limitations of developing countries. Materials such as lime, bricks and several pozzolanas can be produced with almost all the capital requirements being met from local sources. In a review of country case studies on promotion of indigenous cementitious materials,[4/] the investment was found to be as low as $2,500 per 1,000 tons of annual production in the case of gypsum

plaster production in Cape Verde. This level of investment was very reasonable in comparison with an amount of $120,000 to $200,00 required for the same output in a conventional cement plant. Even though the capital requirements for production of indigenous cementitious materials are low, the small-scale investor may be even more limited in access to capital. Sometimes, basic capital inputs are not available on the market, and, where the production process is dependent on imported equipment, such as a ball mill to grind the pozzolana, the constraints in foreign exchange supply and the intricacies of import licence allocation may be impediments to the small-scale investor.

4/ See annex I.

C. Quality of output

41. There is a diversity of available technologies for production of most low-cost materials, but the choice of a particular technology should normally be determined by the type of raw materials to be used and the available forms of energy. In general, the quality of output will depend on the choice of an appropriate technology, given the fact that raw materials will vary in their characteristics from one location to the next. There is always the danger of attempting to adapt one standard technology to different situations, and this can be the single cause of low-quality production.

42. Small-scale labour-intensive technologies for the production of low-cost materials have the advantage of being able to function using small deposits of raw materials, often of an inferior type. However, this advantage could, at the same time, be the cause of an unsatisfactory end-product. For example, for most indigenous cementitious materials such as lime, gypsum and rice-husk-ash, the quality of the parent raw material which is used for production is a significant determinant of the quality of the final output. For this reason, a clear understanding of the basic properties of the raw material is essential to the entire production process. However, the predominant practice in the production of

most indigenous cementitious materials is that the quality of raw materials is taken for granted and assumed to be standard in all cases, so that differences from one deposit to the next are not accounted for in production. The main constraint here is that the level of skills of those using the raw material for production is inadequate, but a fundamental problem is that, even if they acquire the requisite skills, they still have to contend with lack of access to the appropriate tools for identifying the production characteristics of the raw materials.

43. The quality of most building materials which are popularly adopted in construction is promoted through a set of nationally or internationally accepted standards. In most countries, materials, such as Portland cement, steel and glass, are produced to conform to such standards. While standards are a desirable mechanism for regulating quality of production, the first and foremost requirement in achieving this objective is to ensure that standards are available for the types of materials which require quality control. However, in most developing countries, there are hardly any standards for indigenous building materials. Standards institutions are available in several countries but they lack the capacity to deal with the requirements of the indigenous building materials sector.

44. For a few indigenous products, such as fired-clay bricks and tiles, there are opportunities to adapt available international standards to local situations. However, the majority of indigenous materials, such as lime-pozzolana or rice-husk-ash-cement, are relatively new, and there is no basis for adopting a foreign standard. It is likely that, apart from India, where standards have been formulated for a variety of lime-pozzolana mixtures, there are no established standards.

45. Because indigenous raw material sources vary in composition and properties, it will be difficult to formulate one standard for uniform application in a country. For instance, standards for lime will have to be formulated covering a variety of raw material sources. In the same way, standards for lime-pozzolanas available in a country, and the options

available for different mixes and for different uses of the final product. This alone is a resource consuming exercise which many countries cannot afford.

46. Even though standards are the basic framework for promoting quality production, they are only effective if properly enforced. However, the enforcement of standards presupposes that manufacturers have acquired the appropriate production techniques to be able to conform to principles of quality output. Because indigenous materials are relatively new on the market, there is likely to be a gap between standards and actual field production practice. In addition, the production processes for a variety of indigenous materials can be relatively intricate even at the smallest scale of production, requiring several intermediate processes, a single one of which could be the source of low-quality output, if not properly dealt with.

47. For instance, in the production of lime at the cottage scale, efforts in identifying good quality limestone, preparing the appropriate clamp kiln and good firing and slaking of the lime, will all be undermined if the final product is not properly stored. Particularly, for small-scale producers, there is always the disadvantage of their being predominantly illiterate, so that standards will tend to be too technical and incomprehensible to them. Similarly, the formulation of any set of guidelines to ensure adherence to standards of production will have to take into account the constraints of disseminating information to the small-scale producers.

D. Demand for indigenous materials

48. The wide adoption of indigenous building materials depends to a large extent on market conditions, i.e., a large and sustained demand for construction materials. In fact, it can be argued that constraints which limit the adoption of indigenous materials are related to the demand for the products rather than to the production or supply of the materials. The cost of indigenous products in relation to other comparable materials on

the market is an important factor of demand.

49. Thus, demand for indigenous cementitious materials will largely depend on their market prices in comparison with the market price of Portland cement. Very often, the market price of indigenous cementitious materials, such as lime and lime-pozzolana, is high or unattractive, when compared with that of the popular and established product, Portland cement. This is a serious limitation, especially with regard to the fact that the indigenous cementitious materials are meant to be low-cost products.

50. One reason why indigenous cementitious materials are expensive - sometimes more so that Portland cement - is that the latter product often enjoys subsidies of one form or the other. The effect of import subsidies, foreign-exchange rates and related measures can be to make imported factors of production less expensive and, therefore, more attractive than indigenous products. Similarly, through certain trade policies, the directly imported Portland cement can become less expensive than indigenous cementitious materials. Sometimes, even though the cost of production of a unit quantity of Portland cement is higher than that of an indigenous binder, governmental price controls on Portland cement can lead to imbalances in the market situation, thereby making indigenous products far less attractive.

51. Even when indigenous building materials are attractive in terms of market price, there is still the problem of consumer biases against the products. Preference for Portland cement, as against lime or lime-pozzolana, may not be based on considerations of cost or quality but based on non-quantifiable factors of taste or values. In most cases, preference is given to Portland cement and such imported materials for the simple reason that existing building regulations tend to support their popular use in construction. In addition, the inflexibility of building regulations has meant that relatively new materials, such as indigenous cementitious materials, cannot be incorporated in the regulations.

52. The failure to use indigenous materials in government-sponsored construction projects is another serious constraint which limits the wide-scale adoption of the materials. Governments in developing countries are often the single largest client of the construction industry, so that they limit the popularity of materials by not adopting them in their projects. In many countries the regulations and high standards set for government-sponsored buildings inhibit the use of indigenous building materials. Normally, government-sponsored construction projects are accorded a high status symbol in low-income settlements, and promotion of selected building materials is facilitated when they are used in governmental projects. However, indigenous cementitious materials, for example, are yet to have an impact on governmental construction projects, for which reason the remainder of the construction market, notably the low-income shelter segment, accords a low preference to such materials. In most countries, procedures for tendering and awarding contracts for government-sponsored projects prohibit the use of binders others than Portland cement, so that, even where there is a preference to use indigenous cementitious materials, it simply cannot be followed.

E. Inappropriate use of indigenous building materials in construction

53. The lack of requisite skills or techniques in the appropriate use of indigenous building materials in construction could be the single most important factor limiting the wide-scale adoption of such materials. Construction skills are important to the extent that they are linked to the objective of achieving minimum cost of indigenous building materials. An indigenous building material can be sold at a low cost on the market; however, where skills are deficient or where there is a shortage of the requisite skills, the overall objective of low-cost construction will be defeated, because of the excessive use of materials in construction or simply as a result of the prohibitive cost of labour in construction.

54. The basic skill requirements for construction, especially for low-income shelter, are simple and relatively easy to acquire. For example, the use of lime or lime-pozzolana as binders for masonry construction is fairly simple, and skills can be acquired over a relatively short period. Despite the simplicity of using these materials in construction, it still requires some basic training to ensure that skills are available on the market. In most cases, skills to use indigenous materials in construction are taken for granted, on the assumption that locally available skills can be adapted to all situations in the construction market. However, some indigenous building materials are relatively new to local craftsmen and, in the absence of any special training programmes, these materials will remain unpopular.

55. Safety of construction and durability of indigenous building materials depend to an extent, on the competence of the labour force in construction. Where skills are deficient, good-quality products could be wrongly applied in construction, thereby leading to unsafe and non-durable construction and, consequently, making a particular set of building materials unpopular. Most indigenous cementitious materials, for example, are vulnerable to this type of shortcoming and can easily become unpopular as a result of wrong application in construction. Possible areas of error are that lime-pozzolana mixtures for masonry work could be prepared in the same proportions as for Portland cement mixtures, or, the setting time for lime-pozzolana masonry could be assumed to be similar to that of Portland cement, thus resulting in non-durable and unsafe construction.

56. In construction practice, safety principles are often promoted through building codes. Codes of design and codes of construction for various elements of building provide elaborate technical details which guide the local labour force in achieving safe and durable construction. In most developing countries, building codes hardly exist and, where they are available, they are restricted to imported codes of practice for reinforced concrete technology, and, almost invariably, Portland cement is the only binder which

such codes make reference to. For instance, codes of practice for brickwork, foundations and soil stabilization, as well as for concrete products, such as blocks, pipes and precast units, specify the materials to be used in such a way that only Portland cement can be used. For this reason, the contents of existing building codes can undermine the safe application of indigenous cementitious materials and, thus, limit the adoption of the materials in construction.

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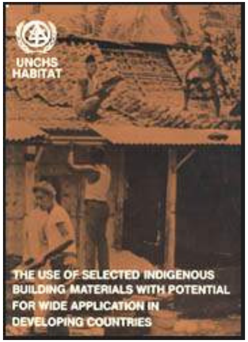

The Use of Selected Indigenous Building Materials with Potential for Wide Application in Developing Countries (HABITAT, 1985, 80 p.)

IV. MEASURES FOR ACHIEVING ADOPTION OF INDIGENOUS BUILDING MATERIALS

A. Transfer and development of appropriate technology

57. Despite the potential contributions that indigenous materials can make to the construction sector and the national economy, and despite the opportunities that exist to promote these materials in several countries, the successful development of these materials is restricted to only a few countries. This limitation can be overcome by the transfer of technologies from countries with successful experience to those countries that have had little or no experience on the subject. The transfer of technology in this manner requires a great deal of international co-operation, but the foremost task is for the country in need of the technology to establish a framework for identifying and receiving the requisite technologies.

58. Local investors are often not aware of appropriate foreign technologies, for which reason measures are required to facilitate the flow of information from foreign sources to the local level. Setting up a local technology-information centre is one way of providing a basis for technology transfer. However, it is desirable to process the information to suit the local conditions.

59. For instance, in the field of indigenous cementitious materials, an imported technology may be appropriate for local use but may still require modifications to be consistent with the inevitable variations in the characteristics of raw materials. Apart from such basic modifications to imported technology, it will be desirable to establish a mechanism at the local level for dissemination of information on the technologies to be promoted. In doing this, consideration had to be given to the producers in the traditional and small-scale sector, some of whom are already in production using obsolete technologies but the majority of whom are not easily reached through conventional methods of information dissemination.

60. The transfer of technology requires, in addition to information flow, training in production techniques. Training of this type should normally be practice-oriented, taking the form of attachments to actual field situations. Alternatively, the training could be organized in the form of a demonstration project or workshop, whereby the imported technology is mounted as a demonstration or as the core of a locally organized workshop for the purpose of training local producers in production techniques. Normally, the cost of initial transfer of technology through training or demonstration projects is quite high, and can only be justified if the new skills to be acquired will benefit a large number of producers. For this reason, it is desirable to devise a national network to spread the skill-acquisition process to the grassroots level.

61. While technology transfer is a desirable process of facilitating the development of indigenous building materials, it is, at the same time, prone to abuse. The transfer of inappropriate technologies is not an unusual phenomenon, and, when this trend goes unchecked over a period of time, the proliferation of inappropriate technologies can lead to a high cost or a low quality of production. In particular, indigenous cementitious materials, such as rice-husk-ash and lime-pozzolanas, are vulnerable to transfer of inappropriate technologies, because they are relatively new, and, moreover, the factors which determine appropriateness of a technology are so variable from one country to another. For these reasons, there is need for a mechanism to screen and select those imported technologies which are worth promoting at the local level.

62. Technology transfer should be seen as a partial strategy for ensuring local technological capacity to produce indigenous building materials. However, in the final analysis, local technological capacity can only be ensured if there is a means to sustain the newly transferred technology, and, ultimately, a country should acquire the capacity to develop indigenous technologies consistent with local resource endowments. In this connection, there should be a locally developed infrastructure capable of promoting the desired technologies for indigenous building materials.

63. In some countries, such local infrastructure can be found in local research institutions which have developed technologies for production of indigenous materials. However, very often, local research institutions require additional inputs, to translate successful innovations into commercial-scale production. Often, an extension-service approach is desirable, to disseminate local innovations to those involved in actual field production.

B. Formulation of standards for indigenous building materials

64. In general, the problem of lack of standards for indigenous materials is due to such standards having to be formulated at each local level. Unlike Portland cement which can have a uniform set of standards, materials such as lime-pozzolana require different standards for all the varieties of lime-pozzolana mixture. Formulation of such standards will require allocation of resources at the national level. It is likely that there will be no local institution with the capacity to undertake this task, for which reason opportunities will have to be sought outside the country for specialized training in standards formulation for selected building materials.

65. Standards formulation is, in most cases, a costly operation, requiring a variety of specialized tools and equipment, and it is vital to make these items available to the local standards institution. For example, a material as simple as lime will require an array of specialized tools and equipment to determine the basic properties of the raw material as well as those of the finished product. Moreover, equipment is required to determine standards for the performance of the material in construction - its strength and resistance to environmental factors. Sometimes, this will require the construction of several pilot structures.

66. Standards formulation is an important basis for promoting quality production of indigenous building materials and, thereby, promoting their wide adoption. However,

standards formulation is only justifiable, if stipulated standards can be enforced. In fact, to some extent, the formulation of standards is not as crucial as the enforcement, because there are opportunities to adapt imported standards to local conditions.

67. Enforcement of newly formulated standards will, first and foremost, require that the standards be widely available to and understood by the target group. For this reason, the presentation of the standards should be in a simple and comprehensive form, taking into consideration the low technical background of those who are actually involved in building materials production. Standards normally indicate what quality of output is expected from producers for specified products. However, it is desirable to provide complementary information on how to achieve the stipulated quality of production. The method of disseminating newly formulated standards and accompanying guides to quality production need not follow a conventional pattern. In some cases, the only effective means of disseminating such information is through actual field demonstration activities.

68. In actual field practice, information on standards of production and a clear understanding of quality production principles are not sufficient provisions for achieving the objective of quality output. The ultimate requirement, to ensure enforcement of stipulated standards of production, is for wide availability of testing facilities for those engaged in production. Again, this is a resource-demanding exercise, considering the possible number of producers requiring access to such facilities and the scattered nature of the location of most producers. A communal approach to the provision of testing facilities is a feasible proposal, but, as much as possible, the process should not be so demanding as to discourage local producers from using the facilities and, thereby, defeat the overall objective of the exercise. At the small-scale level of production, field personnel for testing of output per cycle of production could be employed, but, in addition, simple tools for calibration and for weights and measures could be made available to the manufacturers.

C. Reformulation of regulations, codes and other regulatory instruments

69. The existing building regulations and codes in most developing countries are restrictive in the type of building materials they promote. To the extent that building regulations and codes can influence the choice of building materials, the wide-scale adoption of indigenous materials, such as lime and lime-pozzolana, can only be achieved, if the regulations and codes are reformulated for the purpose of incorporating such innovative materials. The reformulation of building regulations in this manner will provide some minimal encouragement for developers to opt for indigenous materials, and, similarly, the constraints on loans for construction projects using "unregulated" indigenous materials will be minimized. In this way, expanded demand for indigenous building materials could be generated.

70. Building codes are vital for providing technical guidelines for good construction practice, so that the building materials covered in the codes are likely to be used safely in construction. When a particular set of building materials are identified with safe and durable construction, their adoption in the construction market is largely ensured. On this basis, demand for indigenous materials can be promoted if building codes are reformulated making reference to design and construction details on the use of selected indigenous materials.

71. Indigenous materials cover a wide range of items and can be applied for multiple purposes in construction. Moreover, some indigenous materials are still being tested and modified in actual field situations, so that, in most cases, there is as yet no exhaustive list of materials or mixtures of materials and their corresponding use in construction. In reformulating building regulations and codes, there is a danger of specifying the type of indigenous materials to be promoted, but, because of the wide variety of indigenous materials and the flexible manner in which they can be used in construction, a specifications approach to reformulation of regulations and codes will defeat the overall

objective of promoting the adoption of such materials. The reformulation of building regulations and codes, in the context of indigenous materials, should be based on a performance concept whereby the functional requirements- of the material are indicated, but flexibility in choice of material is afforded to satisfy the stipulated requirements.

72. The government, as the single largest client of the construction sector, can play a role in improving the demand for indigenous building materials, by simply adopting such materials in government-sponsored construction projects. However, this can only be achieved if, among other measures, the building codes and regulations and the existing procedures for tendering and awarding of contracts are modified or reformulated. For example, designs of governmental construction projects can be formulated with the sole objective of promoting the use of indigenous materials, and tender documents can be revised or drafted in a manner which encourages the use of indigenous materials. Again, it will be desirable to adopt a flexible approach, taking into account the opportunities for further innovations in the field of indigenous building materials and, thus, making it possible to incorporate innovations without undergoing any further reformulation.

D. Provision of access to credit and capital

73. Because of the low capital requirements for production of most indigenous building materials, there are opportunities for investments by local entrepreneurs. However, these can only become a reality, if the requirements of local entrepreneurs, in terms of credit and capital, are met. Even though the credit requirements for investment in indigenous building materials production are relatively low, they cannot be met within the capacity of existing financial institutions. For this reason, the promotion of such materials will require special arrangements for the provision of credit to entrepreneurs.

74. A large proportion of the credit requirements will be for small-scale operators who may not be able to meet the normal guarantees for the provision of loans by credit

institutions. In addition, a substantial part of credit needs will be for working capital rather than fixed capital. Sometimes, demand for funds and the corresponding payback period will not follow regular procedures of conventional finance institutions. For these reasons, innovative arrangements in the provision of credit to local entrepreneurs is required. One important issue that has to be addressed in this regard is the question of the unfavourable competition which imported materials offer to indigenous materials. Because the cost of production or market price of imported materials is often subsidized, there is need to provide credit at preferential interest rates to entrepreneurs engaged in the production of indigenous materials, so that the latter materials have a chance of being attractive on the market.

75. Sometimes, a relatively small imported input is indispensable for the production of an indigenous building material. However, limitations in the supply of foreign exchange and the cumbersome process of foreign-exchange allocation can be a constraint to the production of indigenous building materials. In order to address this problem, it will be desirable to make basic imported capital inputs available to local entrepreneurs. Certain imported capital inputs can be purchased by governments and made available to interested producers in the form of loans. Alternatively, capital items can be provided on a communal basis. For instance, vehicles for carting clay or limestone from the source of the raw materials to the various production sites can be provided in the form of a plant pool.

E. Provision of access to raw materials

76. Because of the unique importance of raw materials as a factor of production of most building materials, the production of indigenous materials can be enhanced only if the raw materials for their production become easily accessible to producers. For this reason, it is important that measures be devised to make a wide range of raw materials readily available to local entrepreneurs self-help builders and building co-operatives. In

addition, such raw materials should be obtained at reasonable costs and should be of acceptable quality. The first task in making raw materials accessible to a large number of investors is to make information available on the types of raw materials available, the use of the materials in building materials production and the expected production span of the available raw materials. To provide this information in a comprehensible manner could be a challenging task.

77. Efforts will have to focus on identifying a multitude of small-scale deposits of raw materials which cannot normally be discovered by conventional survey methods. Perhaps, the most demanding task will be to make information on newly-found raw material deposits widely available in a manner that could help local entrepreneurs arrive at a decision to invest in the production of indigenous materials. Part of this task will include devising innovative methods of disseminating such information to those already engaged in production, the majority of whom are small-scale operators with hardly any basis for understanding technical information.

78. The exploitation of certain raw materials, such as clay, limestone and gypsum, has legislative implications, and, for that reason, their accessibility can be improved if specific legislative reforms are undertaken. One way in which raw materials can be made accessible for the production of indigenous building materials is by revising or preparing new land-use maps, for the purpose of ensuring that sites which contain suitable raw materials are appropriately classified or zoned. It may also be necessary to see that concessionary rights are granted for such a purpose. In most cases, granting of concessionary rights is a cumbersome and intricate process which can easily put off a potential investor, and, unless these obstacles are resolved by policy changes, there is a likelihood that programmes for the expansion of the supply of indigenous materials will be impeded.

79. Sometimes access to raw materials can become excessive in cost. Where raw

material deposits are located at a distance from transport routes, their inaccessibility could be the cause of this investment in the building materials sector. Particularly for small-scale deposits, it may not be a viable option for an investor to undertake the cost of providing access roads to the source of the raw material. For these reasons, measures are required to enhance the accessibility of raw materials, in terms of improving or providing infrastructure. Non-conventional approaches to the provision of such access roads can be adopted as cost-saving measures. For instance, local contractors can be mobilized through community-participation methods, and the basic inputs of vehicles and equipment for road construction can be provided by public executing agencies.

80. Because of the variable nature of small-scale deposits of raw materials, the notion of accessibility of raw materials to manufacturers will include access to information on the quality of each raw material deposit, in terms of basic physical and chemical properties, and, probably, guidelines on production requirements for each variable deposit. Again, this is a resource-demanding operation which may require an entirely innovative approach. One way to tackle this problem is to provide basic training to small-scale producers on simple methods of assessing the quality of the parent raw materials. For example, there are simple methods for identifying clay types, based on the smell of the material, its texture and similar sensory tests, which can easily be learned by small-scale operators.

F. Institutional support

81. The measures required to achieve use of indigenous building materials are several but, often, interrelated. For instance, the formulation of standards for materials production is closely related to the reformulation of building regulations and codes. Because of the multiplicity of interrelated measures, there is always the danger of duplication of functions or lack of co-ordination of efforts, thereby leading to inefficiency or unnecessary gaps in the expected delivery of support. Thus, without a co-ordinated

approach, implementing all the measures identified above still may not bring about the desired improvements in the production and use of indigenous building materials.

82. An entirely new institution could be established or an existing agency designated to provide the specific function of promoting indigenous building materials. This will involve, co-ordinating the activities of all other institutions delivering specific inputs to the sector. In some countries, institutions exist bearing the responsibility of promoting an overall indigenous industrial sector. However, because of the peculiarities of the building materials sector, it will be desirable to have an institutional arrangement solely for that sector. Because it is a relatively new subsector, in most countries, there will hardly be any existing institution with experience of comparable functions.

83. Apart from providing the basic function of coordination of varied activities, the role of a designated institution could extend to providing overall policy direction, including mobilization of resources to implement measures and activities. Mobilization of resources can be enhanced, if informal institutional arrangements among the producers of indigenous building materials are promoted or strengthened. For instance, small-scale operators could be organized in savings societies, thereby generating funds to support a specialized credit scheme. Another vital role of a designated institution could be to purchase inputs on a centralized basis on behalf of producers and, thereby, achieve economies of large-scale procurement.

84. In order to fulfil the objective of promoting indigenous building materials for the benefit of the low-income population, a designated institution has a crucial role to play in promoting innovative programmes which can satisfy the demands of the target group. This may involve programmes in non-conventional methods of building materials production. For this reason, those types of building materials that are amenable to self-help production methods should be identified, and appropriate programmes should be promoted.

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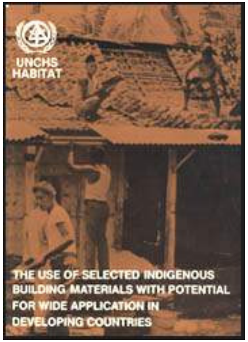

The Use of Selected Indigenous Building Materials with Potential for Wide Application in Developing Countries (HABITAT, 1985, 80 p.)

V. THE PRODUCTION AND USE OF SELECTED INDIGENOUS BUILDING MATERIALS5/

5/ Country case studies on the production of selected indigenous cementitious materials have been provided in annex I.

A. Introduction

85. There is a wide variety of indigenous building material which can be promoted in developing countries to have an impact on the precarious situation in the building materials sector. In general, the type of indigenous building material which can be promoted will vary from one country to the next. However, it is possible to focus attention only on those indigenous materials that are likely to have a remarkable impact on the building materials sector and above all, those that are of significance to almost all developing countries. Indigenous cementitious materials fit into this category for at least two related reasons. In the first instance, unlike some other innovative indigenous building materials, there is demonstrated know-how on the production and use of indigenous cementitious materials. Secondly, by virtue of the wide variety of raw materials which can be used in producing indigenous cementitious materials, it is likely that most countries possess one or any other type of raw material for the promotion of such an indigenous building material.

86. In developing countries, consumption trends for Portland cement have shown a rapid increase over the past 20 years, but the rate of import has been equally significant. For example, imports of cement rose from 54 per cent of total consumption in 1970 to 80 per cent in 1979. In monetary terms, the negative trade balance for the cement industry alone grew from $900 million in 1970 to over $1.7 billion in 1979.[6/] Domestic production of Portland cement, for the same period, increased in all developing regions, notably showing a 64 per cent increase in Africa and a 13.6 per cent increase in Asia. In some particular cases, developing countries have become net exporters of cement.

6/ United Nations, Yearbook of International Trade Statistics, 1979.

87. Despite the trends of rising imports and expansion of domestic production, Portland cement is still not available in sufficient quantities and, in any case, is only available at costs which are prohibitive to the bulk of the population. The main reasons for this

situation is that foreign-exchange constraints have limited quantities and kept costs high for imported products, and, because domestic production is generally dependent on imported inputs, the same limitations apply to the local product. Unfortunately, in most developing countries, the only binder used in the construction sector is Portland cement, so that its limited supply and high cost have meant that investments in construction are either withheld, diverted or abandoned. Even though Portland cement is not a low-cost material, its application as the sole binding material is popular with the low-income population, to the extent that it has become a crucial factor in the inadequate delivery of shelter to the low-income population.

88. Portland cement has a clearly defined role as a binder in fulfilling the functional requirements for high-strength applications. However, in actual construction practice, Portland cement has become a ubiquitous material, largely as a result of its wrong application in construction. Portland cement is predominantly used in low-strength applications, for foundation concrete, plasters, mortars and soil stabilization. The wrong application of cement in this manner is not only unnecessarily costly but, more important, technically defective.

89. For example, Portland cement, as a binder in the preparation of mortars, produces a mortar which is too harsh, of low workability and, sometimes, stronger than the blocks to be bonded. Portland cement is often used in preparing concrete for ordinary strip foundations, to support single-storey structures such as farm sheds and basic rural dwellings. Again, Portland cement is frequently used as a stabilizer in the preparation of soil blocks, yet it is the wrong choice for certain soils such as clayey soils or black cotton soils.

90. The degree to which Portland cement is wrongly applied in construction has reached alarming proportions, and it is estimated that only 20 per cent of world-wide use of

cement requires the strength of Portland cement.[7/] In some countries, this situation has come about because there is hardly any alternative binder to Portland cement, but, in a few countries, there are low-strength binders which can be used in place of Portland cement at low cost and with good performance, yet the predominant choice of the market is cement. However, in almost every developing country there are opportunities, based on known and established technologies, to produce binders or cementitious materials which, even though not exact substitutes for Portland cement, can serve the same function in construction and, most of all, can be produced within the resource limitations of developing countries, using indigenous factors of production. As explained below, indigenous cementitious materials can be produced and used in a variety of ways, thus offering individual developing countries a vast range of options to improve the availability of binders to suit their particular conditions.

[7/] UNIDO, "Optimum scale production in developing countries", Sectoral Studies Series, No. 12 (Vienna, 1984)

B. Lime

91. Before the advent of Portland cement, lime was the main binding agent used for construction, and, despite its-decline in popularity, its use as a binder is still valid. Portland cement and lime have one basic common property when mixed with water - they have the tendency of setting and hardening so that they are subsequently strong and impervious to water. Lime has a slower setting rate than cement, and the final strength is lower, but lime is perfectly adequate for most low-strength applications, such as mortars, plasters, foundation concretes and building blocks. In addition, lime has additional qualities, such as good workability, ability to accept movement without cracking, water retentivity and resistance to water penetration, thus making it more suitable than Portland cement for masonry work.

92. The raw materials for manufacturing lime are, normally, naturally occurring substances, such as limestone, dolomite, sea shells or coral (see annex II for an overview of raw materials for lime production in Africa). In most countries, information on available raw materials for lime manufacture has been restricted to large-scale deposits, particularly high-quality limestone suitable for cement production. However, for the purpose of low-strength binders, there are vast opportunities in terms of raw materials, including a multitude of small deposits. Lime can also be obtained as a residual product in the manufacture of sugar, paper and acetylene. Thus, the variety of sources from which lime can be obtained offers an opportunity to promote the material in several countries and in different parts of a country.

93. Lime can be produced with different technologies covering a wide range of scales of production. In general, there are large-scale, capital-intensive production technologies and small-scale technologies, often labour-intensive or adopting rudimentary techniques in production. Small-scale technologies normally satisfy an output of 1-50 tons per day, and the demands for such small-scale technologies, particularly for outputs of less than 10 tons per day, can easily be met within the capacities of most developing countries.

94. The main capital items in small-scale lime manufacture are a kiln and a storage shed, both of which can be locally fabricated with hardly any imported inputs. Kilns vary in terms of their efficiency in burning the raw material, but basically there are two types of kilns at the small-scale level: batch kilns and continuous fired kilns. The type of kiln and the efficiency of burning influence the quality of the final product. Lime production is energy-intensive, and the process of transforming the raw material (limestone) to hydrated lime is achieved through the firing stage, so that energy is the single most important factor of production. The fuels commonly used in lime manufacture, at the small scale, are firewood, coal and residual oil, however, the available fuel determines the type of kiln that can be used.

95. Even though small-scale lime production is relatively labour-intensive, it still requires some basic skills. Some basic understanding of the raw material is desirable as the first step in quality control. The fabrication of the kiln is a skilled operation, and so is the firing process. Similarly, careless slaking, storage and packaging of the fired product can undermine the entire objective of quality production.

C. Pozzolanas and lime-pozzolanas

96. In general, pozzolanas are classified into two groups: natural and artificial. A pozzolana is a material which, on its own, is not cementitious but, with the addition of lime, reacts to form a material which sets and hardens. Thus, for the purpose of construction, a pozzolana is not an end in itself but, rather, a means of achieving the ultimate product - lime-pozzolana. Lime-pozzolana is a low-strength binder used in the same manner as lime, to prepare mixtures for mortars, plasters and building blocks and for soil stabilization. Normally, a mixture of one part of lime to two parts of pozzolana is adequate for lime-pozzolana binders, and, even if a ratio of 1:1 is applied, considerable savings of about 50 per cent of the available supply of lime is achieved. In this way, where pozzolana is obtained at a lower cost than lime, lime-pozzolana becomes an attractive material for low-cost construction.

D. Natural pozzolanas

97. Natural pozzolanas are basically of volcanic origin and are usually found in areas which have experienced volcanic activities. For example, in Africa, natural pozzolana deposits can be found in six countries -Burundi, Cameroon, Caper Verde, Ethiopia, Rwanda and the United Republic of Tanzania (see annex III for a brief description). Pozzolanas of this type occur either in a pulverized state or in the form of compact layers, and this, in turn, determines the production process which the pozzolana has to undergo before being mixed with lime to produce a binder.

98. Where volcanic tuff occurs as a naturally fine-grained material, it requires no preparation apart from ensuring that it is sufficiently dry prior to mixing with lime. Sun-drying is feasible, even though a small-scale, locally fabricated kiln can be used for this purpose. For example, the Arusha-Moshi area of the northern part of the United Republic of Tanzania is volcanic, and large deposits of fine-grained pozzolanas are widely available. These deposits which require no grinding after quarrying can be mixed with lime to prepare mortars, plasters and building blocks.

99. Where the natural pozzolana occurs in a coarse-grained form, it is desirable to dry the material, either in the sun or a kiln, and, thereafter, grind it in a ball-mill to the desired fineness, ready for mixing with lime. In some instances, the grinding of coarse-grained pozzolanas is restricted to the preparation of mortars and plasters, while the preparation of blocks is feasible without any grinding. For instance, in Lembang, Indonesia, unground coarse-grained pozzolana is mixed with 20 per cent lime and sufficient quantities of water to produce solid blocks for building construction.

E. Artificial pozzolanas

100. Unlike natural pozzolanas, artificial pozzolanas are obtained only after the basic materials undergo some basic production processes. The raw materials from which artificial pozzolanas are obtained are extensive in scope, covering materials of geological origin and agricultural and industrial residues. However, the most common raw materials used for production of artificial pozzolanas are as follows:

> **(a) Clay products. Suitable clay deposits can be quarried, fired and ground into fine powder in a ball-mill, for use as a pozzolana. Basically, most soil groups containing the common clay minerals can be used for this purpose, but plastic clays, such as those used for pottery, are the most likely to produce good pozzolanas. The firing of the clay should be under controlled temperatures, and a**

locally fabricated kiln or incinerator can be used for this purpose. The desired temperature for firing is around 600°C. As an alternative to firing raw clays, pozzolanas can be produced by grinding bricks or tiles obtained as residual products in the production of fired-clay bricks and tiles. Here, the only equipment required is a ball-mill or a hammer-mill to grind the material. Sometimes, the pozzolana and the lime are mixed and ground together in the ball-mill.

(b) Rice-husk-ash. Rice-husk is the residual product from milling rice. It often has no commercial value but, rather, poses a problem of disposal. The ash which results from burning rice husk is a pozzolana which reacts with lime and water to produce a binder suitable for low-strength masonry application. Normally, about 20 per cent of the volume of rice husk results in ash, and, because rice is grown in several countries, rice-husk-ash is potentially an important cementitious material. In Africa alone, there are about 40 countries where rice is grown, and, even though the quantity of output is not high enough in all the countries to justify commercial-scale production of rice-husk-ash, the potential that exists for promoting the material is encouraging (see annex IV for details on rice-husk availability). As a pozzolana, rice-husk-ash is produced under controlled temperatures of about 600°C in a kiln or incinerator. The incinerator for burning rice-husk can be locally fabricated, and, in countries where production has been commercialized, the scale of production if often as small as 1 ton per day. Apart from the incinerator, which can be locally built in bricks, the main capital item required for rice-husk-ash pozzolana manufacture is a ball-mill to grind the ash or ash and lime into a homogenous fine mix. In some countries, the ball-mill may have to be imported but, in a country such as India, it is readily available on the market.

(c) Fly-ash. Fly-ash is the residual product obtained when coal is fired and, thus, occurs as a waste product from coal-fired power stations. It is desirable for the

fly-ash to be in a dry state prior to use. Often, fly-lash occurs in a coarse form and will have to be pulverized before mixing with lime to produce a binder, so that the main capital item required in preparing fly-ash pozzolanas is a ball-mill for pulverizing the ash to the desired fineness.

F. Blended cements

101. Blended cements are produced by mixing ordinary Portland cement with a "low-cost" cementitious material, notably, blast-furnace slag, lime or any of the popularly adopted pozzolanas. The principle behind blended cements is to obtain a binder which is nearly equal in strength to Portland cement but, at the same time, cheap in cost. Examples of blended cements are Portland-pozzolana, Portland-slag or Portland-lime pozzolana. There are cases where blended cements have been produced by replacing about 25 per cent of the volume of Portland cement with a pozzolana, and the resulting binder is recorded to have satisfied the same 28-day strength test as for normal Portland cement. Blended cements have an advantage over Portland cement in terms of workability and water resistance.

102. The production of blended cements is in two stages. First, the production of pozzolana and, secondly, the intergrinding of pozzolana or lime with Portland cement. The use of rice-husk-ash to produce blended cements has been gaining popularity over other types of pozzolana, and some demonstrations have indicated that up to 50 per cent of Portland cement can be replaced by rice-husk-ash, with only a marginal reduction in the strength of the resulting binder compared with normal strengths of Portland cement. The cost implications of blended cements could be very encouraging, as demonstrated in Rwanda[8/] where pozzolana-lime-cement is estimated to be 50 per cent the cost of Portland cement.

8/ See annex I for details.

103. Unlike lime-pozzolana, the production technology for blended cements is relatively intricate. First, the production presupposes the availability of Portland cement; secondly, it is desirable to produce a finely ground pozzolana for the purpose of blending with the cement. However, the part of the operation which requires careful control is the intergrinding of the pozzolana or lime with the cement into a homogenous mixture, of uniform degree of fineness. For these reasons, blended cement manufacture is, in general, a capital-intensive process even though the capital-intensity per ton of output is still far less than Portland cement.

G. Gypsum-based binders

104. Gypsum in another naturally found mineral of widespread availability from which cementitious binders can be made, for use in mortars, plasters, concretes, blocks and prefabricated building products. The properties of gypsum plaster are rather different from those of either Portland cement or lime-based cements, and its suitability as a cement-substitute is, therefore, limited to particular uses. Unlike other cementing materials, gypsum plaster sets rapidly, even when setting retarders are added; it is somewhat porous and of rather lower strength than Portland-cement-based materials; and it is slightly soluble in water.

105. Its rapid setting makes it very suitable for internal renders; blocks can be made from it if they are cast immediately after mixing, and gypsum concrete can be made by pouring a fluid water/plaster mix into moulds already containing coarse aggregate. All of these uses must be restricted to internal applications or dry conditions, because of gypsum's water-solubility. The most common use of gypsum is in the manufacture of thin reinforced sheets - fibrous plaster sheeting or plasterboard - using vegetable fibres, glass fibre or cardboard sheets as reinforcement. The outstanding fire resistance of

gypsum plasters makes such sheets especially good as internal partitions.

106. As with lime-pozzolana binders, gypsum-based binders involve a very simple manufacturing process which can be carried out at small scale. The firing temperature, around 170°C, is much lower than that of lime, which means that gypsum-plaster manufacture is energy-saving an important advantage in areas where fuel is scarce. Two recent projects which made use of gypsum as a cementitious binder are those in Cape Verde Islands[9/] and at Noumerate, Algeria, reported by GRET.[10/] The physical qualities, low energy cost and adaptability to small-scale production are advantages of gypsum production.

9/ S. Cramer, Gypsum Production on Maio Island (Berlin, Institute for Geologie, 1979).

10/ Gypsum Plaster: Its Manufacture and Use in Building (Paris, GRET, 1982), translated for ITIS by B.M. Booth.

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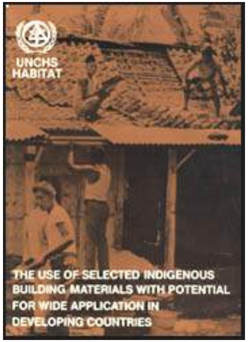
The Use of Selected Indigenous Building Materials with Potential for Wide Application in Developing Countries (HABITAT, 1985, 80 p.)

Annexes

Annex I: CASE STUDIES ON PRODUCTION OF SELECTED INDIGENOUS CEMENTITIOUS MATERIALS



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Annexes

Annex I: CASE STUDIES ON PRODUCTION OF SELECTED INDIGENOUS CEMENTITIOUS MATERIALS

A. India: production of cement in mini-scale plants

1. The potential for small or mini-scale cement plants in India has long been recognized, for the reasons set but in chapter I. Experimental work first began in 1948, but, at first, severe difficulties were encountered in producing standard quality ordinary Portland cement (OPC) and capital costs appeared high relative to output. In the 1970s, further efforts were stimulated by severe supply shortages and by certain policy interventions on the part of the government to promote small-scale cement manufacture. Four separate organizations have now developed technologies, based on different assumptions about appropriate scale, level of technological sophistication and raw materials flexibility. In all four cases, the plant uses a technology based on the vertical shaft kiln (VSK) which has inherent advantages in fuel economy over the rotary kiln (RK) used for standard large-scale plants.

2. The Cement Research Institute (CRI), inheriting early developments by the Ministry of Defence, has developed kiln designs for various scales of production (30, 50 and 100 tons per day), and these designs have been licensed to a number of machinery manufactures who have developed the materials handling and grinding equipment, and supplied the plants. The Regional Research Laboratory at Jorhat has also proposed kiln designs based on scales from 1 ton per day to 100 tons per day, and these are commercially exploited by the National Research and Development Corporation. Engineer D. P. Saboo, working with Shree Engineers at Jodhpur, has developed a very low-cost design for an entire plant, using a 25-3O ton/day kiln, requiring very limited sophistication in plant fabrication, and with low electrical power requirements.

3. These three plant designs depend on raw materials of a similar quality to that required for large-scale plants. The fourth design, now under the control of ATDA (Appropriate Technology Development Association) of Lucknow, is designed to use both low-grade and variable raw materials, such as the marls and kankar deposits in the Ganges plain area of Uttar Predesh, where demand for cement is high but no cement-grade limestone is available. The plant design, which has been under development intermittently since

1965, is based on a 25 ton/day kiln, with sophisticated raw-material preparation equipment to cope with variable quality supply.

4. All four designs have obtained government certificates to the effect that OPC to Indian Standards can be manufactured. Of the 19 plants in commercial production in 1985, eight use CRI technology, eight use Saboo technology and three use RRL technology. A further 43 plants altogether are on order. ATDA still has only the pilot plant operational, and this is not yet in full commercial production.

5. A recently completed economic study of the mini-cement industry in India by Economic Development Associates of Lucknow[a/] compares present performance with the stated objectives and reveals interesting comparisons.

(a) Each of the designs can produce cement for sale with a respectable profit margin. Mini-cement plants no longer have exemption from excise duty or any concessions other than exemption from price controls. However, because of low transport costs, the retention price to the producer is substantially higher than that of large-scale manufacturers, while production costs are only slightly higher in the case of mini-cement plants. Profits, as a percentage of sales realization thus appear on paper to be higher for mini-cement than for large-scale cement plants. However, much depends on capacity utilization.

(b) There is little tendency for the mini-plants to be established at small deposits of limestone: most are in already established limestone areas, and there is, at present, little evidence of dispersed production.

(c) Transport costs are significantly reduced by comparison with the average. Only about 10 per cent of the selling price is transport, compared with 16 per cent on average for cement produced in India; transport costs in distribution alone are

2 per cent for mini-cement plants, compared with nearly 10 per cent on average.

(d) Packing and distribution costs are not reduced, since most of the cement produced by mini-cement plants is packed in jute bags for sale through dealers - the normal practice.

(e) Investment costs per ton capacity are significantly lower than those for large-scale plants, but tend to increase as the scale of production decreases. The lowest-capital plant, the CRI 100 ton/day design, has a capital cost per ton less than half that of large-scale plants currently being installed. Table 1, shows some relative capital costs.

(f) Gestation periods are short. Mini-plants can be brought into production in 12 to 18 months, as opposed to three to four years for large plants.

(g) The employment potential varies, but employment potential is not high. The use of CRI technology instead of large-scale technology for an anticipated expansion of capacity of 37 million ton per year by 1995 would increase employment from 50,000 to 140,000. Comparative employment potential is shown in table 1.

(h) Although the designs are all well within the capability of the Indian machine-making industry to fabricate, they are not unsophisticated in operation. Engineering staff are not needed, but skilled technical staff are, and close supervision of production is essential for profitable operation.

(i) The development of mini-cement production plants has done nothing to stabilize or reduce cement prices in India. The profitability of each plant depends on selling cement at or above the existing market price which is up to four times

the prevailing market price for cement in Europe. The use of cement in construction has always been restricted to the richest 20 per cent of the population, rural or urban, and this will not change.

(j) Small entrepreneurs will be unable to afford the capital costs. The principal beneficiaries of the newly developed technologies are likely to be "intermediate" entrepreneurs.

a/ A Technology for the Intermediate Entrepreneur: the Place of Mini-cement in the Indian Economy (Lucknow, Economic Development Associates, 1985).

Table 1. Capital and employment implications of investment in cement capacity

	ATDA (25 ton/day)	CRI (100 ton/day)	Large-scale (2,250 ton/day)
Capacity (tons)	37	37	37
Number of plants[a/]	4 993	1 122	50
Capital investment:[b/]			
Fixed	3 741	2 211	5 365
Working	429	401	335
Total	4 170	2 612	5 700
Employment (thousands)	602	140	51

Source: Economic Development Associates.

Notes:

a/ Assumed average size of 0.75 tons per annum for new plants.

b/ Rupees x 10^7 (1985).

B. United Republic of Tanzania: lime-pozzolana project at Oldonyo Sambu

6. Since 1974, the Small Industries Development Organisation (SIDO) in the United Republic of Tanzania has had a programme to develop village lime industries throughout the country. SIDO has to date established 10 semicontinuous kilns, on the Indian Khadi and Village Industries Commission (KVIC) design, of capacities ranging from 1 to 10 tons of lime per day. In 1976, when this programme was well under way, the SIDO Regional Office in Arusha began considering the possibility of using the local volcanic ash from Mount Meru as pozzolana. A feasibility study was carried out and samples taken from near the Ward of Oldonyo Sambu, 35 km north of Arusha, showed high pozzolanic activity. With a 1:2:9 by weight lime: pozzolana: sand mixture and a water content of 15 per cent, 25 mm cubes after seven days under water gave strengths in excess of 6 N/mm^2.[b/] These results and the known existence of other ash and limestone deposits in the area were considered an adequate basis for the establishment of a small-scale project to exploit lime-pozzolana (pozzolime) in building.

b/ N/mm^2: Newton per square millimetre.

7. The aim of the project was to develop appropriate technologies for producing and using pozzolime for small-scale building, and to establish a number of units in the Arusha area producing pozzolime-based materials. The project began in August 1977, funded by SIDO and OXFAM. Oldonyo Sambu was chosen as the best location for a pilot unit,

because it was centrally situated with regard to pozzolana, firewood and water, and also the nearest settled community to the limestone deposits.

8. The limestone was found in the plains 20 km north of Oldonyo Sambu. It was a hard surface crust (Kunkar) with an average calcium carbonate content of 70-75 per cent. The kiln was built by local masons between October 1977 and February 1978. It was based on a standard KVIC design and was basically a vertical cylinder, 1.2 m in diameter and 4.5m high, with thick (1.0 m) masonry insulated walls. The people who constructed the kiln were given one month's training in lime production, and this was enough to enable the workforce to begin regular production. The kiln operated continuously, alternate layers of sized limestone and firewood being fed in at the top, and calcined quiklime being withdrawn from the bottom. The manufacture of the pozzolime was straight forward: the volcanic ash was blended with lime in equal parts with hand shovels, and the final product was sieved through a 3 mm sieve before being packed in 20 kg. bags. The maximum output of the kiln was 3 tons per day, but 1 ton per day could regularly be achieved. The lime produced contained about 70 per cent calcium hydroxide, which was as good as much of the lime available in the United Republic of Tanzania, and had a ready market.

9. Tests were carried out to demonstrate the use of the pozzolime mixture for plastering and mortars, and lightweight pumice-pozzolime blocks were also made, of standard 450 x 225 x 150 mm dimensions. Normal 28-day strengths of 2.0 N/mm^2 (1:2:6 lime-pozzolana-sand) and 3.0 N/mm^2 (in blocks) were achieved. During two trial periods of production, in 1978 and 1979, about 30 tons of lime, 10 tons of pozzolime and 5,000 blocks were produced, most of which were used to build a store for the project and a clinic for the local village, but some of which was sold.

10. Cost calculations, based on this production experience, showed that pozzolime could

be sold, including a 10 per cent margin, at 36/- per 50 kg or 720/- per ton, against 1080/- per ton for Portland cement (when this was available). Pozzolime blocks could also be sold for 6/-, against 8/- for equivalent-sized concrete blocks produced in Arusha. Some economic data are shown in table 2.

11. Ownership of the industry was transferred in 1980, to the local village administration which had been given responsibility for raising funds (through a collection) for a truck and working capital to continue production. For various reasons, little further production had taken place by July 1981, at which time a thorough evaluation study was made by SIDO for OXFAM, the project's original sponsor. The evaluation[c/] included a survey of 91 villages in the villages of the Oldonyo Sambu ward, and a comparative costing of using lime-pozzolana against other materials.

[c/] Evaluation Report of Phase 1 Lime pozzolana Project at Oldonyo Sambu Ward, Arusha Region (Dar-es-Salaam, Small Industry Development Organisation, 1981).

12. The evaluation found:

(a) That the material and the production method were basically sound, and that abundant raw material still existed;

(b) Even though substantially cheaper than cement (50 per cent savings on walling costs, when lime-pozzolana was compared with cement for blocks and mortar), the local villagers were still too poor to be able to buy the material;

(c) The project depended heavily on local truck transport for its raw materials supply and for sales, and lack of its own transport had been a serious disadvantage;

(d) A particularly prominent example of misuse of the material (to render a mud-and-wattle wall of traditional construction), where failure had occurred, many have had a counter-demonstration effect;

(e) There had been insufficient consideration given in the project design to involving and educating the local people, and the local leadership had failed either to take an interest or help promote the project.

13. Subsequently the industry was selected by the Economic Commission for Africa as a site for a demonstration and training unit on lime-pozzolana production. It was also reported to have been taken over by the United Republic of Tanzania Army to supply material for barracks construction. The present status is not known.

Table 2. Lime-pozzolana production at Oldonyo Sambu, United Republic of Tanzania: some economic data

Location		Oldonyo Sambu, Arusha
Raw material		Kankar limestone Volcanic ash pozzolana
Fuel		Firewood
Products		Lime, lime-pozzolana, pozzolime blocks
Production capacity:	Lime	1-3 tons per day
	Lime-pozzolana	2-6 tons/day
Capital cost of plant:	Fixed	100,000/-
	Working (est)	40,000/-
	Total	140,000/-

Foreign-exchange cost	Nil
Production cost per ton pozzolime	660/-
Labour cost per ton pozzolime	240/- (18 mandays & 14/-)
Fuel used (firewood) per ton pozzolime	0.37 tons
Transport cost per ton pozzolime	222/- vehicle hire
Cement replacement ratio	Approximately 2.0

Source: J. Sakula and J. Sauni, Oldonyo Sambu Pozzolime Industry; History, Operation and Development (Dar-es-Salaam, SIDO, 1980).

C. Rwanda: production of lime-pozzolana

14. PPCT (Project Pozzolana-Chaux-Tourbes) is a small industry, in the town of Ruhengeri in north-western Rwanda, which produces both lime and lime-pozzolana cement. PPCT was established in 1979 as a collaboration between a Belgian-financed non-governmental organization (COOPIBO) and the Government of Rwanda, after six years of research in Kigali by COOPIBO on the development of local building materials. Until 1980, all cement was imported to Rwanda, but, although a small OPC plant had been established, the 1985 ex-factory price was $280 per ton; transported to other parts of the country, the cement cost $340 per ton - about the highest price in the world.

15. Ruhengeri lies at the base of the volcanic Virungas mountains and has access to several small limestone deposits and large quantities of volcanic ash: for fuel, a eucalyptus plantation and a peat march are nearby, and a waterfall provides hydro-electric power potential. The objectives of the project are given by Schilderman[d/], in a report for COOPIBO, as:

(a) To develop a cheap binder which might partly be substituted for Portland

cement;

(b) To create employment in an area with a population density exceeding 350 per km^2, a shortage of agricultural land and high unemployment;

(c) To develop co-operative ownership of the industry, with particular attention to the social welfare of its participants; and

(d) To use an alternative fuel (peat) in order to save firewood and avoid importing fuel.

d/ T. Schilderman, “The case of a lime-pozzolana industry in Rwanda: the PPCT” (unpublished report) (COOPIBO, September 1985).

16. Limestone is obtained by hand-quarrying from a deposit about 5 km from the factory. The limestone is in three layers separated by soil and impure limestone, requiring sorting. Fuel for clacining the limestone is peat from a peat marsh 1.5 km from the factory, which is cut and dried seasonally. The stone is calcined in a mixed-feed vertical-shaft kiln with a mean diameter of 2 m and a height of 9. It is then slaked in tanks, dried and sieved. The kiln has a capacity of 720 tons per year. Some of the lime produced is sold, but most is used for producing lime-pozzolana binder.

17. The pozzolana used is derived from a volcanic ash cone located about 40 km from Ruhengeri. This is dried in a specially constructed kiln and then interground with lime and Portland cement in proportions 25/12.5/62.5 of OPC/lime/pozzolana. Grinding is carried out in a vibrating ball-mill to a fineness of 3,500 to 4,000 cm^2/gm (Blaine). The binder is then bagged, for sale as a masonry cement, in bags containing an explanation of proper use. Current production is about 120 tons per month.

18. Some economic data on the industry are given in table 3. At a selling price of $170 per ton, the binder is far cheaper than OPC and cheaper to use in 60 per cent of the country even allowing for use of larger quantities to achieve the same results. The demand for the product at this selling price greatly exceeds production. About one quarter is bought by big contractors, half by development projects, and a quarter in small quantities by individuals, mainly for housing. Its use is restricted to single-storey buildings for plasters, underfloor concrete and masonry works.

19. A recent evaluation of the project by Schilderman[e/] notes a number of technical and organizational problems which are being experienced:

(a) There are difficulties, both of accessibility and quality, in all the available limestone deposits;

(b) The pozzolanas, even finely ground, are only moderately active, and an unacceptably large proportion of OPC is needed to accelerate hardening;

(c) The capacity of the ball-mill is in reality much less than indicated by the manufacturer and assumed in the project planning, and interruptions to the milling sometimes occur due to the need for repairs and cuts in electricity;

(d) The peat marsh has proved difficult to drain, and pumps will be needed to exploit deep layers;

(e) Lack of experience of the project staff and absence of similar projects elsewhere made design of the factory difficult, and some miscalculations were made;

(f) There are currently no accepted standards for lime-pozzolana binders in

Rwanda, so the binder has not been accepted until now for governmental projects, although a set of standards has been proposed and is under discussion;

(g) At 700 tons per year the industry is not yet economically viable, and an expansion to 3,000 tons per year has been proposed, at which level the industry would be economically sound at current production costs.

e/ T. Schilderman, op.cit.

The potential demand is estimated at about 20,000 tons in 1987.

Table 3. PPCT Project at Ruhengeri, Rwanda: some economic data

Location	Ruhengeri, Rwanda
Product	PPCT binder based on pozzolana, lime and cement
Production characteristics:	
Investment	$440,000
Number of employees	52
Investment per work place	$8,620
Import component of production cost	53.3 per cent
Energy consumption per ton of product	0.437 tons peat 20 kwh electricity
Sales:	
Sales price	$170 per ton, ex-factory
Level of sales	700 tons per year

Availability	Ex-factory

Source: COOPIBO.

D. Indonesia: production of lime-trass binders

20. There are many deposits of natural volcanic pozzolana or trass in Java, which, when mixed with locally produced lime, gives a hydraulic cement. The deposit at Lembang, near Bandung, has, for many years, been used as a raw material for the manufacture of lime-trass blocks.[f/] The mixture used is 20 per cent lime and 80 per cent trass, no additional aggregate being added because of the coarse content of the trass. Blocks are both hand-moulded and machine-moulded: standard block and brick formats are produced.

[f/] Z.A. Abbas, The Development of Building Materials for Housing in Indonesia (Bandung, Directorate of Building Research, c. 1977).

21. There are numerous small industries practising in the vicinity of Bandung, and other similar deposits are used in other parts of Java. The blocks are cheaper than other masonry materials, and are very popular for cheap housing. Technical problems are slow setting, high shrinkage and wet/dry movement which can cause cracking in walls; these problems can be overcome, to some extent, by long curing periods before the blocks are used. Economic data on these industries are unfortunately not available.

E. India: production of lime clay (surkhi) binders

22. Surkhi is a traditional pozzolanic material used in India. It is normally made by grinding reject bricks or tiles in a hammer-mill or ball-mill. In some places soil is burnt, specially in crude kilns or clamps, and then pulverized.[g/] Such surkhi is coarse and not

very reactive but gives sufficient strength, in the Indian climate, to enable mortar for brick and stone masonry to set and harden.

g/ R.J.S. Spence, Appropriate Technologies for Small-Scale Production of Cement and Cementitious Materials (Intermediate Technology Industrial Services, 1979).

23. Various processes for the manufacture of improve or reactive surkhi have been developed and reported,[h/] but these do not appear to have been widely taken up. The most detailed scheme is that proposed by the Khadi and Village Industries Commission, to produce a lime-pozzolana mixture called Lympo.[i/] Table 4 gives capital costs for production at three different scales, based on 1977 prices. A feasibility study on this material was conducted by a Kerala Government Committee in 1975,[j/] in which comparative costs of alternative mortars were calculated, using lime-pozzolana and cement. These are shown in table 5. The report assumed that a 1 : 3 Lympo mortar can replace a 1:6 cement mortar and that a 1 : 4 Lympo mortar can replace 1:8 mortar, batched by volume. This implies a replacement rate of 1.7 tons of Lympo per ton of cement, and it can be seen that there is very little cost advantage in the lime-pozzolana mortar.

h/ Ibid.

i/ Lympo (Bombay, Khadi and Village Industries Commission, 1975).

j/ Government of Kerala, Report of the Committee Constituted to Study the Question of Making Available Lime and Surkhi For Building Construction, (unpublished report, July 1975).

Table 4. KVIC 'Lympo' lime-pozzolana: expected economies at three different scales of production

Scheme		A	B	C
Capacity tons per day		2	5	10
Investment[a/]	Rs	20,000	45,000	80,000
	£	1,300	3,000	5,200
Working capital	RS	10,000	15,000	30,000
	£	720	980	1,960
Power required	h.p.	5	10	15
	kW	3.8	7.6	11.2
Employment total number		5	10	15

[a/] **Investment includes for kiln and all machinery: excluding land and building.**

Table 5. Comparative cost of Lympo and cement mortars in Kerala (In Rupees, 1975)

Sand Lympo mortar	1 : 3	116.75	1 : 4	91.25
Sand cement mortar	1 : 6	120.60	1 : 8	96.00

24. The advantages of the material are in reduced capital cost, increased employment potential (of great importance in Kerala) and ability to use local raw materials to replace scarce cement. The establishment of 100 units each producing 10 tons per day was recommended, but the current status of this programme is not known. Increased production of Portland cement in India since that time, has, to some extent, alleviated

the shortage, and the economic incentive for the production of alternatives has diminished correspondingly. Equally, the recent development of lime-pozzolana cements based on rice-husk-ash, which requires no fuel in its processing, has made surkhi and Lympo production non-competitive.

F. India: production of lime-rice-husk-ash cements

25. The potential of rice-husk-ash(RHA) as a pozzolanic material has been known for some time, but the small quantities available in any one area have always been seen as a disadvantage. In the 1970s, the search for appropriate small-scale technologies for rural areas, coupled with experimental work at the University of California[k/] and the Asian Institute of Technology,[l/] demonstrating the very superior pozzolanic qualities of RHA, has led to a worldwide resurgence of interest and development activity. Efforts at commercial development have been particularly concentrated in South Asia, in India and Pakistan, where manufacturing processes have been developed in a number of research institutes, and licenses purchased by entrepreneurs to set up production.

k/ P.K. Mehta, "Properties of blended cement made from rice-husk-ash", ACI Journal, Title 74-40, September 1977.

l/ D.J. Cook, R.P. Pama, B.K. Paul, "Rice-husk-ash lime cement mixes" (Bangkok, AIT).

26. There are three different processes available. In the process proposed the Indian Institute of Technology (IIT) Kanpur, the rice-husk is burnt in open heaps, which is the normal practice for its disposal, before being brought to the works for grinding. This is the cheapest technology but permits no control in the temperature and time of firing. The Indian Cement Research Institute (CRI) and the Pakistan Council for Scientific Research

(PCSR) have developed processes for controlled burning, using small incinerators. Although this involves extra handling and capital cost, it avoids the variability of the open-heap process, and, particularly, the danger of producing crystalline or non-reactive ash, which can occur if temperatures rise above about 700°C. The incinerators also provide scope for the use of thermal energy from the ash-burning for other processes, such as crop drying. In both processes, after burning, the ash is interground with lime in proportions around 1 : 2 in a ball-mill for a period varying from one to six hours: there may be a period of separate grinding of the ash before the lime is added. Lime is usually brought in rather than burnt in the same location, and, in some cases, additives are used to improve the setting time. The RHA cement is then bagged for sale as a masonry cement, to be used with sand in proportions of 1 : 3 or 1 : 4 in mortars. A third process has been developed by the Central Building Research Institute (CBRI), using waste lime-sludge, from the sugar industry, and rice-husk as raw materials. The two materials are formed into balls and sun-dried. The balls are then fired, using the rice-husk as fuel, in a trench kiln, before being ground for one hour in a ball-mill.

27. In all cases, the scale of production is small, around 2-10 tons per day. All the equipment needed including the ball-mill, can be manufactured locally in small workshops. Some of the plants produce blended RHA/OPC mixtures as well as lime-pozzolana cements. This application will be discussed in section H. A review of the current status of the technology was prepared for ITIS by R.G. Smith of the United Kingdom Building Research Establishment, after a visit to India, Pakistan and Nepal in 1982.[m/] Smith found that the technology was technically viable and, according to all reports, commercially successful, giving good return on investment. Some comparative economic data are shown in table 6. He found however, that the commercial plants faced various technical and production difficulties:

(a) Problems with maintenance and power availability led to frequent shut-downs

and loss of production;

(b) There were disagreements between entrepreneurs and consultants about the correct technology to use, especially in burning;

(c) In Pakistan, alternative uses for rice husk (e.g., as fuel) restricted availability and destroyed the commercial viability of the operation;

(d) The properties (compressive strength, setting times) claimed by manufacturers were mostly not achieved in samples tested in the United Kingdom.

m/ R.G. Smith, "Rice-husk-ash cement: progress in development and application", Intermediate Technology Publication, 1984.

Table 6. Economic comparison of various production methods for RHA cement in India

Country	Location	Cost of ash (£ per ton)	Cost of lime (£ per ton)	Cost of making RHA cement (£ per ton)	Selling price of RHA cement (£ per ton)	Local selling price of OPC (£ per ton)	Capital cost (£)	Capital cost per ton per day (£)	Net annual cost (£)	Net annual cost per ton (£)	Return on investment (percentage)
India	A1	1	8	19	27	95	12 000	6 000	12 000	18	32
	B			30	50	Higher than the cement	7 000	5 000	8 000 to 14 000	15-30	
	B1				40-53						

	B1				40-52						
	C	3		28	36		42 000	2 500			
	D			10	13		10 000	2 000	10 000	10	20
Nepal	E1				55	90	10 000				
	E2	10	40		60	90	6 000	8 000			
Pakistan	F1	2	15	10	Not sold	100	1 600	500			

G. Botswana: the production of blended cements

28. The Moshaneng Limeworks is one of a group building materials projects initiated by the Southern Rural Development Association (SRDA) in conjunction with the local government's Production Development Committee (PDC) for the Southern District of Botswana. A large area of Botswana is arid and, therefore, sparsely inhabited. The most populated part of the country is the fertile south-eastern section, much of which falls within the borders of the Southern District. Thus, there is a comparatively large demand for building materials in this district, as well as in the nearest town, Lobatse, and the capital, Gaborone. This demand was filled almost exclusively by products from neighbouring South Africa which is also where many Botswana go to find employment. The objectives for establishing local building materials production were, therefore twofold; first, to limit Botswana's almost total dependence on South African imports and, secondly, to create employment in the Southern District.

29. The first projects to be undertaken by SRDA were fired clay brick production, slate quarrying and the cutting of tiles, extraction and processing of mineral pigments, stone crushing for roadstone and terrazzo chips, and lime production. Users of lime in Botswana include the copper smelting works, the construction industry, the Rural Roads Department, the Department of Agriculture, farmers and tanners. All the lime needed was imported from South Africa. The Moshaneng Limeworks was implemented to reduce this

dependence on imported lime and to create employment locally, requiring only the skills available in Moshaneng and neighbouring villages. Subsequently, in 1984, a grinding and blending plant was established, alongside the Limeworks, for the production of a blended cement, known as Setswana Cement, and this is now in production.[n/]

[n/] R. Shrestha, Setswana Cement (to be published).

30. The raw material for the lime production is dolomite, available as waste from an old mine, avoiding the need for either quarrying or crushing. The dolomite has a total oxide content of 89 per cent. Fuel is low-grade coal mined in Botswana, with a calorific value of 22 MJ/kg. The stone is fired in a small vertical-shaft kiln of 1.10 m internal diameter and 3.60 m height using the Khadi and Village Industries Commission (KVIC) design.[o/] The kiln is operated on a semi-continuous basis, producing about 2.3 tons of lime per day, with a fuel consumption of 6,700 MJ per ton of hydrated lime. The quicklime is hand-slaked on a platform, screened through a 5-mm screen and, then either bagged for sale or used as an input for the blending process.

[o/] UNIDO "Lime in industrial development", Sector Study No. 18 (UNIDO/15/555), August 1985.

31. The blended cement consists of a mixture of 50 per cent Portland cement, 10 per cent lime, 10-15 per cent brick waste and the remainder coal ash. The Portland cement is imported from South Africa, the brick waste is from the SRDA brick plant nearby, and the coals ash is obtained from the power house of the Botswana Meat Commission in Lobatse, 45 km away. The lime, coal ash and brick waste are gound together in a ball-mill for two hours; an equal weight of Portland cement is then added, and the materials are then further ground for an unspecified period. The ball-mill was manufactured locally and uses granite pebbles from the river banks as a grinding medium. The blended

mixture is packed into standard-sized paper bags for sale at $3.50 per 25 kg bag, against $4.50 per bag for imported cement. The blended cement is claimed to meet the requirements for rapid-hardening cement.

32. Currently production is limited by the size of the ball-mill to 100 bags per day but an expansion to 40 tons per day production is envisaged, with a resulting lowering of the price. Some economic data on the project are given in table 7.

Table 7. Setswana cement production at Kanye Botswana: some economic data

Location	Kanye, Botswana		
Raw materials	Dolmitic limestone (mine waste) Coal ash Brick waste Portland cement		
Fuel	Coal		
Products	Lime, blended Portland-pozzolana cement		
Production capacity (ton/day):			
Lime (hydrated)	2.3		
Cement	2.5		
Capital cost	Lime kiln	Fixed	16,000 dollars
		Working	7,000 dollars
	Grinding	Unknown	
Foreign exchange costs	Cost of grinding plant		
Production cost ($ per ton cement)	120		

Labour cost ($ per ton cement)	23
Cost of imported cement ($ per ton)	180
Fuel used per ton cement	34 kg coal for lime burning; fuel content of cement grinding energy
Cement replacement ratio	1.0

H. India: production of blended cements

33. Numerous laboratory studies have shown that mixtures of rice-husk ash (RHA) and Portland cement (OPC), either blended or interground, have remarkably good strength development properties. While standards for Portland-pozzolana cement generally do not allow more than 25 per cent addition of pozzolana (usually PFA or volcanic ash), it has been shown that 1:1 mixing of OPC and RHA can have setting and strength development rates comparable with OPC. Since the cost of lime, weight for weight, is usually higher than that of cement, it is often advantageous for a small rural RHA cement plant to intergrind with cement rather than lime and offer for sale a material with properties comparable to OPC, at a low price.

34. The Indian Institute of Technology[p/] has developed a material, known as Ashment, which can be made with varying mixing ratios - 2 : 3, 1 : 1 or 1 : 2 RHA to OPC, and 1:1 RHA to PPC. The RHA is obtained by selection from boiler ash or from open-field disposal heaps. It is first ground separately in a ball-mill and then mixed with OPC or PPC, either in a ball-mill or by hand. Ashment technology has been taken up by a number of producers who manufacture it alongside RHA lime-cement, called Ashmoh. Production capacity depends on the size of the ball-mill used, but IIT claims that using the 1.5 m x 1.5 m ball-mill, the capacity is up to 1,000 tons per annum of RHA, although 50O tons per annum is more likely than the higher figure.

p/ P.C. Kapur, and A.S.R. Sai, ASHMENT Cement, Indian Institute of Technology, Kanpur, 1980.

35. At one plant using Ashment technology alongside Ashmoh, visited during 1982 by Smith[q/], the mixing ratio was 1:1 RHA to PPC, since OPC was difficult to obtain. The price for this product was little more than 50 per cent of the open-market price for cement. When tested in the United Kingdom, the Ashment had substantially lower strength and longer setting times than claimed by the promoters, though still very adequate for masonry work.

q/ R.G. Smith Rice Husk Ash Cement; Progress in Development and Application, Intermediate Technology Publications, 1984.

36. In Thailand, pilot plants for small-scale production of RHA-cement blends have been established at the Asian Institute of Technology[r/] and Khon Kaen University[s/], and extensive testing of the products has been carried out. No reports of commercial production plants based on these technologies are available.

r/ Y.C. Loo, P. Minityongskul and P. Karasindli, "Economic rice husk-ash cement", Building Research and Practice.

s/ P. Chindaprasirt, Low-cost Cement for Rural Areas (Faculty of Engineering, Khon Kaen University, 1983).

I. Philippines: production of blended cements in Cebu

37. In the Philippines - a voluntary housing organisation in Cebu City - Pagtanbayayong[t/] has developed a pozzolanic binder from mixtures of 70 per cent fly-

ash, 10 per cent lime and 20 per cent OPC. Four hours ball-milling is required, and the cost is 50 per cent that of OPC (excluding interest on capital). Commercial production, at a scale of 0.8 tons per day, started in 1984.

t/ Pagtambayayong, Progress report on Pozzolanic Cement Binder Project 1983/84 (unpublished).

J. Cape Verde: production of gypsum plaster

38. During field studies in 1977 for an Integrated Rural Development Project on the Island of Maio, Cape Verde, Stefan Cramer, a geologist from the Berlin Institut fr Geologie, noted the availability of huge deposits of gypsum sands in an area unsuitable for cultivation. At that time, the Government was considering plans for the establishment of a cement factory, and Cramer recognized that the gypsum could provide a raw material for this industry and, also, be used as the basis for a locally-produced construction material which could reduce construction costs and bring employment and training to the villages. Working in conjunction with the Government, Cramer developed a very simple small-scale technology for the production of gypsum plaster and helped to establish a pilot production unit and a workers' co-operative to run it. A second co-operative was established to make building blocks using the gypsum plaster.

39. The basis of the technology is a simple rectangular kiln, 1.5 x 2.0 m in plan and 1.0 m high. The top surface of the kiln is a flat steel sheet made by flattening old oil drums. This surface is heated from below, and the gypsum, after sieving and some drying, is spread on it in an 8O mm deep layer. Calcination takes 30-45 minutes, during which time the gypsum is turned over from time to time with a wooden rake: it is then left to cool and is bagged for sale or for block-making. Daily production capacity is 1 ton, and the fuel used is firewood available in adequate supply locally; approximately 250 kg of firewood are used for each ton of gypsum plaster produced.

40. The technology has been described by Cramer[u/] who gives the economic details shown in table 8 and has written a production manual. In 1980 a visit was made to the industry by Smith[v/] whose evaluation noted:

(a) That the product had gained acceptance locally, mainly for the building of blocks, since the rapid set (7 minutes) made it difficult to use for mortar or plaster;

(b) Comparative costs of Portland cement, lime and gypsum plaster were as shown in table 9;

(c) Some simple improvements were possible in the production process to improve working conditions and the quality of output;

(d) The addition of a liquor made from boiling fish bones was able to retard the set by an hour or more;

(e) Performance of the plaster and blocks was so far satisfactory, but it was too early to assess long-term durability.

[u/] S. Cramer, Gypsum Production; A Manual (Ilha do Maio: Projecto de Gesso, Berlin, Institut fr Geologie, 1979).

[v/] R.G. Smith, "Small scale production of gypsum plaster for building in the Cape Verde Islands", Appropriate Technology, 1982.

Table 8. Economic data on Gape Verde gypsum project

Raw material:

Proven reserves	Approximately 300,000 tons gypsum
Purity	90-98 per cent gypsum
Estimates reserves	1-2 million tons

Processing:

Personnel	6 women, 2 men
Kiln	Capacity: 1,000 kg raw gypsum per day Energy requirements: 0.25 kg wood per kg raw gypsum

Applications:

Plastering	Gypsum - sand ratio = 1 : 2 or 1 : 3
Gypsum blocks	Gypsum - sand - gravel = 1 : 1 : 2
Mortar	Gypsum - sand ratio = 1 : 1 or 1 : 2

Costs:

Production costs (50 kg)	$1.8
Selling price	$39 ton
Investment cost	Kiln: $28 (2 oil drums, 2 sacks cement)
Equipment:	$8

Production cost structure: 73 per cent

Personnel 73 per cent
Fuel 14 per cent
Freight 13 per cent

Table 9. Comparative prices of gypsum, lime and cement in Cape Verde 1983 (Escudos per tonne)

	Imported	Locally produced (from kiln)
Cement	5 600	-
Gypsum plaster	16 000	1 400
Lime	20 000	1 700 - 3 000

Note: 100 Escudos = approximately £1 sterling 1985.

Annex II: INFORMATION ON LIMESTONE DEPOSITS IN AFRICAN COUNTRIES

Country	Known occurrences/location/quantity	Suitability	Current use
Burkina Faso	Limestone at Tambu and Bobo-Dioulasso	50,000 ton cement plant being planned at Tambau. Cement plant being discussed for Bobo-Dioulasso	Artisanal production of lime based on deposit at Bobo-Dioulasso
Burundi	Matongo - 5 million tons (CaO: 30-50 per cent, MgO: 0.5-5 per cent)	Cement	Lime is being produced at Bukumba, and Busiga, Makamba

			Bubanza on small scale
	Cibitoke region - 300,000 tons (CaO: 20-50 per cent)	Lime	
	Bubanza - not estimated		
	Busiga - Too small for industrial exploitation	Lime	
	Dolomitic limestone		
	Kasenyi (kajeke) - 50 million tons (MgO: 0.5-20 per cent)	Lime production	
	Cibitoke - 200,000 tons	Lime	
	Mosso region - 10 million tons (MgO: 1-25 per cent)	Lime	Artisanal production of lime in Mosso region
Cameroon	Deposits in northern part at Bizder (over 4 million tons) and Fiquil (about 900,000 tons). Also limestone bearing strata observed in mountains near Douala.	Cement and lime production	Cement plants at Bonaberi, near Douala, and Fiquil in the north. Hydraulic lime produced in Douala.
Congo	Limestone deposits in region of Loutete and Jacob on the Brazzaville to Pointe-Noire rail line at 315 km from Brazzaville. Reserves estimated at over 100 million tons.	Studied for cement production	
Djibouti	Deposit about 91 km from Djibouti.	Cement and lime	Proposals for

	Estimated reserves about 30 million tons of high quality limestone.		setting up plants for production of cement and lime under discussion.
Ethiopia	Rich in limestone deposits at Dire-Dawn, Addis Ababa, Massawa. Others situated in the Blue Nile valley and in different locations in Tigari and Harrar provinces. Several other deposits across the country.	Cement	Cement produced at Dire Daqa, Addis Ababa and Massawa.
Gabon	Deposits of Coniquest Island estimated at over 5 million tons	Cement	
Gambia	Clam shells available. No economic limestone deposits located yet. Known deposit has overburden of 400 metres which limits development possibilities.	Shells are suitable for lime production	Artisanal burning of shells to make lime. No organized commercial production.
Ghana	Limestone deposits at Nauli (over 13 million tons), Wenchi, Buipe-Banka, Bongo-Da (2.2 million tons) and Oterkpolu. Other deposits at Anyaboni, Kitampo, Abeasi, Daboya, Salega-Yeji area. Dolomitic limestone at Buipe, Daboya, Longoro, Kaguruge Kago, Bongo-Da (about 5 million tons), Walewale and	Although Nauli lime-stone is suitable for cement production, large overburden makes exploitation uneconomical at this time. Wenchi deposit also has large overburden. Small-scale cement plant is	Artisanal lime production at Oterkpolu Private entrepreneur produces lime from shells

	Kanjaga Clam shell deposits occur mainly on the banks of the Bolta River, north of Akuse from Amedika to Bator. About 700,000 tons available for exploitation	proposed at Bongo-Da and Oterkpolu deposits found suitable for lime production. 40,000 tons per year lime plant to be established soon at Buipe Clam shells are suitable for lime production	
Guinea	Deposits at Souguta (exact reserves not known; studies in progress), Amali, Sigure and Kakoulima (near Conakry)	Cement and lime production	300,000 tons cement plant being planned at Souguta. Mini-cement plant being considered for Sigure.
Guinea Bissau	Limestone available in western part of country. Studies in progress to estimate quantity and suitability for building materials production. 100,000 tons of clam shells spread over small islands south-west of mainland	Studies in progress Suitable for lime production. Small scale plants could be set up.	
Kenya	Limestone is very abundant. Coral limestone on the coast; limestone at Kunkar, South Nyanza		Lime is being manufactured at Mombasa, Tureka and Koru
Madagascar	Deposits at Majunga, Ibity (in region of		The Majunga

	Antsirabe), Saolara (south of Tullar). There are several other deposits that could be exploited.		deposit serves an existing cement plant
Malawi	Chalugame deposit		Serves existing cement plant
Mali	Limestone deposits in five of the nine regions. Deposits at Diamou, Astrou, Kayes, Bafoulable. Clam shells are also available.	Suitable for production of cement and lime	Cement being produced at Diamou. New cement plant to be set up at Astrou. Lime produced by UCEMA at Djikoroni, 5 km from Bamako using Diamou limestone. Artisanal production of lime from clam shells.
Niger	Limestone at Balbaza	Cement	About 30,000 tons cement being produced annually.
Nigeria	Sokoto limestone deposits: 100 million tons+; Ewekoro: 35 million tons+; Makurdi: 20 million tons+; Calabar: 10-15 million tons; Other deposits at Nkalagu, Yandew		Cement is currently being produced at Ewekoro, Calabar, Nkalagu, Sokoto, Ukpilla, Shagamu,

	Ashaka		Ashaka and Yandew.
Rwanda	Travertine limestones occur at Mashyuza, Gishyuta, Kalonzi and Rwaza-Pengu. The Mashyuza deposit is estimated at over 60 million tons.	Good quality. Could be used for cement or lime production. Small-scale lime plants planned.	Plant being built at Mashyuza to produce 50,000 tons of cement per year
Senegal	Limestone deposit at Rufisque estimated quantity 25 million tons.	Cement production	Cement plant at Refisque has been operating since 1948
	Limestone deposits also at Pout, estimated at over 80 million tons, and at Casamance	Suitable for cement and lime production	Artisanal production of lime. Govern- mental project for commercial production of cement and lime at Pout is in the pipeline.
	Sea shells available at some locations	Lime production	Artisanal production of lime from sea shells
Somalia	Good limestone deposits near Berbra and Mogadishu		
Sudan	Pure limestone at Wadi Khurmut on west bank of the Nile, near Atbara.		

	Deposits in Shereik area, northern province, at Jebel Nyfr near Jebelein, Blue Nile Province, and at Jebel Saqadi, near Sennar. All dolomitic		
Togo	Three main deposits of limestone at Tokpli, Avta and Mango (clam shells). Six deposits of dolomite occurr at Gnaoulou, Pagala, Djamd, Mdj, Amou and Akposso. Small deposits at Bohoul, Kamina Nakane, Kltchpk	Tokpli deposit suitable for cement production. Avta deposit could be used for lime but is limited because of high P_2O_5 content (3.5 per cent). Deposit has been reserved for cement production. Mango clam shells suitable for lime production. Dolomites tested and found generally suitable for lime production.	CIMAO project of Togo, Ghana and Cte d'Ivoire based on limestone deposit in the region of Tokpli
Uganda	Deposits at Tororo, Suku Hills and Kasese		Existing cement plants depend on deposits at Tororo and Suku Hills
United Republic of Tanzania	In all regions. Over 250 known occurrencies in Arusha, Coastal, Dodoma, Iringa, Kilimanjaro, Kigoma, Lindi, Mara, Mbeya, Morogoro, Tanga regions.	Deposits suitable for lime manufacture are found in Arusha, Dodoma, Iringa, Kilimanjaro Lindi, Mara, Mbeya, Morogoro, Tanga	Local lime burning in Arusha, Dodoma, Iringa, Morogoro regions. Commercial lime

		regions	plants - Marwa and Sanya lime works (Kilimanjaro) Mbeya lime works (Mbeya) Darlime works (Dar-es-Salaam). 16 lime kilns set up by SIDO
Zaire	Several deposits of lime- stone found in various parts of country. For example, deposits in Kivu province are: Katana - Luiro, large but not estimated; Katana-Koukondo, 2 x 10^6 m^3; Rutshuru, 800,000 m^3; Indata 4 x 10^6 m^3, Rumangabo, 1.3 x 10^6 m^3. Other important deposits occur in Bas Zaire, Shaba and Haut Zaire provinces. The deposit in Kisangani area (Haut Zaire) estimated to be infinitely large - 525 m thickness over hundreds of km^2 of area.	Deposits suitable for cement and lime are found	Cement is produced in five plants in two provinces. There are two large commercial producers of lime (for own consumption) some 20 other small lime plants across country
Zambia	Extensive reserves of limestone found in the Kundelungu in Lusaka, Mumbwa, Kafue Solwezi and Copperbelt areas.	Ndola deposit suitable for lime production	Deposit at Chilanga is being exploited for

	Deposits at Chilanga, Ndola.		cement production
Zimbabwe	Several limestone deposits scattered across the country. Evaluated reserves are over 700 million tons.		

Other countries with limestone deposits[a]

[a] **Details on limestone deposits in these countries are not available from the secretariat of the Economic Commission for Africa.**

Algeria
Angola
Benin
Botswana
Cape Verde
Cte d'Ivoire
Egypt
Lesotho
Liberia
Libya
Mauritius
Morocco
Mozambique
Tunisia

Annex III: INFORMATION ON NATURAL POZZOLANA DEPOSITS IN AFRICAN COUNTRIES

Country	Known occurrences/location/quantity	Suitability	Current use

Burundi	Pozzolana (trass) deposits in Bujumbura area estimated at 1 million tons. Deposits also found around Cibitoke and Musongati.	Decomposed lava from Cibitoke tested and found to be active. Volcanic rock from Musongati area also found to be active. Trass in Bujumbura area is very active.	Plant for production of pozzolana cement at Bujumbura ENACCI considering setting up lime plant to aid production of lime pozzolana
Cameroon	Pozzolana found in the volcanic mountains near Douala		About 18,000 tons of pozzolana are produced annually
Cape Verde	Large deposits of pozzolana found in islands		
Ethiopia	Owing to early volcanic action, pozzolana materials are found in abundance all over the country. Pozzolana, identified as pumice, scoria, volcanic ash.	Investigations on sample of scoria shown it can be used as partial replacement of portland cement up to 25 per cent	Pumice used in manufacture of pozzolana cement at Addis Ababa cement factory
Rwanda	Large quantities of pozzolana are found around Gisenyi and Ruhengeri		A pilot plant for pozzolana cement is in operation at Ruhengeri
United	Owing to early volcanic activities,	Little work done on chemical	Lime-pozzolana

Republic of Tanzania	pozzolanas are found in many regions. There are about 40 known occurrences. Large ones are in Mbeya-Rukwa area (18 occurrences) and Arusha region (13 occurrences). Pozzolana identified as pumice, yellow fine-grained tuff, volcanic ash.	analyses of pozzolana. Laboratory tests on samples from Oldonyo-Sambu show that 20 per cent replacement can be make in Portland cement without violating strength requirements.	plant at Oldonyo-Sambu, Arusha.

Annex IV: RICE-HUSK AVAILABILITY IN AFRICAN COUNTRIES

Country	Paddy production a/ (1,000 metric tons)				Quantity of rice husk b/ (1,000 metric tons)			
	1978	1979	1980	1981	1978	1979	1980	1981
Algeria	-	1	1	1	-	0.2	0.2	0.2
Angola	20	20	20	20	4	4	4	4
Bnin	9	10	16	16	1.8	2	3.2	3.2
Burkina Faso	28	30	29	29	5.6	6	5.8	5.8
Burundi	8	10	8	8	1.6	2	1.6	1.6
Cameroon	46	45	55	55	9.2	9	11	11
Central African Republic	16	18	13	15	3.2	3.6	2.6	3
Chad	40	30	45	47	8	6	9	9.4
Comoros	16	16	14	14	3.2	3.2	2.8	2.8
Congo	4	4	4	4	0.8	0.8	0.8	0.8
Cte d'Ivoire	504	534	511	550	100.8	106.8	102.2	110
Egypt	2 358	2 507	2 350	2 500	471.6	501.4	470	500
Gabon	1	1	1	1	0.2	0.2	0.2	0.2

Gabon	1	1	1	1	0.2	0.2	0.2	0.2
Gambia	25	21	34	33	5	4.2	6.8	6.6
Ghana	60	55	62	79	12	11	12.4	15.8
Guinea	366	348	350	330	73.2	69.6	70	66
Guinea Bissau	40	35	23	23	8	7	4.6	4.6
Kenya	42	43	40	40	8.4	8.6	8	8
Liberia	244	249	243	216	48.8	49.8	48.6	43.2
Madagascar	1 914	2 250	2 109	1 999	382.8	450	421.8	399.8
Malawi	50	50	38	40	10	10	7.6	8
Mali	252	177	125	142	50.4	35.4	25	28.4
Mauritania	4	4	4	6	0.8	0.8	0.8	1.2
Mauritius	-	-	-	-	-	-	-	-
Morocco	22	28	13	17	4.4	5.6	2.6	3.4
Mozambique	52	70	70	62	10.4	14	14	12.4
Niger	32	24	32	38	6.4	4.8	6.4	7.6
Nigeria	515	600	1 090	1 241	103	120	218	248.2
Rwanda	3	4	5	4	0.6	0.8	1	0.8
Senegal	140	122	59	120	28	24.4	11.8	24
Sierra Leone	500	527	513	400	100	105.4	102.6	80
Somalia	6	6	4	5	1.2	1.2	0.8	1
Sudan	10	7	7	8	2	1.4	1.4	1.6
Swaziland	5	5	5	5	1	1	1	1
Togo	23	17	24	21	4.6	3.4	4.8	4.2
Uganda	11	13	17	14	2.2	2.6	3.4	2.8

Uganda	11	13	17	14	2.2	2.6	3.4	2.8
United Republic of Tanzania	260	250	215	200	52	50	43	40
Zaire	213	230	246	250	42.6	46	49.2	50
Zambia	4	4	2	6	0.8	0.8	0.4	1.2
Zimbabwe	5	5	-	-	1	1	-	-
Total Africa	7 845	8 367	8 397	8 559	1 569	1 673.4	1 685.2	1 711.8

Notes:

a/ **Source: FAO Production Yearbook, 1981, vol. 35**

b/ **Assuming husk constitutes 20 per cent of paddy.**

Rice husk availability (1980)
Countries with 10,000 tons/year (or more)

Country	Estimated quantity (1,000 tons)
Egypt	470
Madagascar	422
Nigeria	218
Sierra Leone	103
Cte d'Ivoire	102
Guinea	70
Liberia	49

Zaire	49
United Republic of Tanzania	43
Mali	25
Mozambique	14
Senegal	12
Ghana	12
Malawi	8

INTERNATIONAL YEAR OF SHELTER FOR THE HOMELESS

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