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PRIORITY AREAS OF FURTHER AND NEW BUILDING RESEARCH ACTIVITIES IN AFRICA

M80-1566

I. Introduction

1. From the earliest times of man's evolution, shelter has been one of his basic concerns, first as a personal daily necessity and later as an outlet for his innovative skills. In the course of time his concept and needs of shelter have expanded quantitatively and qualitatively in response to social changes and modern conditions and shelter has acquired a wider implication going beyond the limits of personal needs and acquiring an economic, cultural and social tinge. These changes in turn have led to experimentation with a variety of building materials and building techniques. On the principle of using whatever material was available locally and readily, each country gradually developed its own basic construction system in line with its rural and non-rural needs. However, changes have been slow. Also they have nowhere reached a final point and the scope for further improvement and innovation is continuously recognized. It is a striking fact that building and building materials research is very much a feature of the development activities of all countries and is particularly prominent in economically advanced countries. The purpose of this paper is to outline its inadequacies in the African region, highlight specific areas of development priorities and indicate, where relevant, possible means of promoting action to implement the priorities.

II. Present position

2. The building materials in use in the African region in varying degree are as follows:

- Natural stones
- Agricultural fibre wastes
- Timber
- Common clay and soil blocks
- Burnt clay bricks, tiles
- Lime
- Cement and cement products including asbestos-cement sheets
- Corrugated sheet iron
- Sheet aluminium
- Structural iron, steel and aluminium
- Sheet glass
- Ceramics (sanitary ware, tiles, pipes)

3. The choice of materials is determined by the particular environment of their utilization (that is, rural, urban and peri-urban), functional considerations, availability and cost and use facilities.

4. Methods of construction have evolved gradually and been adapted to readily accessible materials. There is a sharp distinction between rural and urban constructions in terms of materials, design and consequently of building techniques. Changes in materials and techniques have been relatively swift in the case of urban building, where natural materials like stone have given way to cement, glass and metal; the use of the latter has demanded different types of skills and services and facilitated some degree of mechanization and standardization in building.

5. Cement and cement products are the most widely used basic materials and have displaced stone, mud, bricks, and other indigenous and traditional materials. The use of

cement has also led to the widespread use of steel in the form of structural steel, resulting in the gradual displacement of the traditional timber reinforcing material. The glamour of cement has escalated the demand for it so rapidly and widely that it now has to be imported to most African countries because of inadequate domestic production 1/.

6. Likewise, corrugated sheet iron (and in some cases aluminium sheet too) has become the principal material for roofing as well as for other purposes, with the difference that, unlike cement, it has become an essential item for the peri-urban and even the rural sections of the population and for urban squatter settlements. Most countries have to import this item also.

7. Of the other materials, glass and ceramics are secondary building materials with exclusive functions. Demand for them is at present confined to urban constructions, but will eventually spread to rural areas. These materials too are generally imported.

8. Except in sophisticated urban constructions and in the use of building materials like cement, steel and aluminium, all of which are derived from foreign systems, there is no hard and fast technology in building systems and in the production of building materials and there is a good deal of variation from country to country. Consequently, much construction work in Africa seems to be based on antiquated methods and lacks a scientific approach to the production of building materials and their use. Many building materials, for example, bricks and tiles, are of indifferent quality and fail to conform to recognized standards, thereby affecting the quality and durability of constructions and necessitating repeated building, repairs and expenditure.

9. Another common problem in the peri-urban sector and in parts of the urban sector is that design criteria barely fulfill the minimum standards of construction as embodied in building regulations and do not come up to the requirements of health and safety standards, thermal insulation and protection from natural hazards such as rain and water seepage, heavy winds, earthquakes, atmospheric corrosion etc. The situation is even worse in the case of rural constructions, most of which are self-designed and self-made and do not come under building codes and regulations.

III. Factors of weakness

10. Clearly, the new materials and the new techniques for using traditional materials have not caught on sufficiently to justify expectations of achieving self-reliance in the 20th century. This situation arises from the following major weaknesses:

(i) Lack of organized information flow and communication and technology development;

(ii) Absence of special policies and backup (direction, promotion and dissemination);

(iii) Shortages of raw materials, project finance, professional skills and trained manpower;

1/ Trends of consumption, production and imports of selected building materials in the African region (Annex I).

(iv) Lack of quality control and standardization systems;

(v) Institutional gaps and weaknesses;

(vi) Inadequate public interest and involvement;

(vii) Absence of requisite co-operation arrangements among countries.

11. Research efforts must therefore concentrate on solving the basic problems and creating a suitable environment for the growth of technologically sound building materials and construction industries.

IV. Approach to research

12. Building materials and building services together constitute the construction sector and are closely interrelated, each basically influencing the quality and effectiveness of the other. Accordingly, the priority for research is an integrated approach to the distinctive problems of each of them on a clear basis of policy support and institutional back-up.

13. A sad feature of most research in most countries is its low status; it is regarded as a tolerable and useful activity but for some reason there is no conviction or recognition that it can make a vital contribution to the development of its associated discipline. Where there is a genuine appreciation of and concern for the potential of its contribution and there is a high degree of probability that it will be used effectively (for example, in nuclear, space, medical, electronic and transport research etc.), the growth of purposeful research has been spectacular. The failure of [illegible] research in many areas has been due to initial lack of clarity of its goal and its non-applied nature. The second requisite of promoting building research is therefore to help it to be self-sustaining, by designing suitable machinery to ensure its practical use if the outcome of the research is promising. Research facilities must therefore be such that laboratory results can be transformed to the pilot plant scale and demonstration plants can be set up.

14. The third requisite is the basis of research programme planning. It has to be relevant and responsive to an immediate or a long-term specific need. The most practical and convenient way of meeting this responsibility is to plan and organize research consultation with industry and other would-be users of the research findings. They can help in the process of identifying the magnitude and priority of the problem to be researched.

V. Perspective of research

15. Building research, like transport and communications research has several inter-related components and must therefore take a wide view.

16. Since the building materials and construction industries are a key sector of the national economy and have a basic infrastructural linkage with several economic activities, building research has to be undertaken in the light of national needs and priorities. A national research basis and focus for research is therefore essential.

17. They also have a regional impact because they are a direct input to human settlements development. Also, of course, although the African region as a whole has adequate reserves of the basic raw materials required for the production of the basic building materials like steel, cement, aluminium, glass etc., this does not apply to every single country of the region since the raw material resources are, in geological terms, scattered. This factor has in the past, hampered the expansion of building materials production facilities in some countries devoid of such resources. Similarly, energy resources in the form of coal, peat and petroleum though not available in each country, are adequate within the region as a whole for meeting the needs of all the countries. After a review of this situation, the African Governments have recommended 2/ that building materials and construction industries development councils should be set up in each subregion to initiate and develop joint projects on specific aspects concerning the growth of this sector. Development of raw materials and energy inputs, production of building materials like cement and bricks and common research facilities are expected to be some of the major activities under this arrangement through the agency of the existing systems of country groupings and economic communities and other co-operation arrangements. These developments will also provide a good background for organizing building research at regional level in order to supplement and support the national research efforts and fill the gaps in respect of specific needs. It is vital for national research systems to be involved as active promoters and partners in these intended regional activities.

VI. Priority areas for further research activities

(i) Some guidelines

18. Some basic guidelines of approach may be useful in this context. The effectiveness of building research will depend upon the extent of its ability to cater for the basic elements of (a) building materials and (b) construction services, since the two together make up the construction sector as a whole, are inter-dependent and grow together. Research must take into account the development process shaping them and ranging from economic policy and promotional aspects to the inputs and supports of production and construction and the efficiency of their management.

19. Research must take account of the basic features of urban and rural constructions in particular, the techniques and materials of their construction and the environment of their development, identify the factors of weakness and assist in bringing about required changes through the development and acceptance of appropriate materials and construction technologies.

(ii) An outline of research priorities

20. The following outline of research priorities is therefore recommended:

(a) Techniques for optimizing the production of critical building materials (primarily cement) from existing plant capacities;

(b) New technologies for using traditional building materials and local materials for improving the quality of rural buildings;

2/ Report of the ECA Meeting of African Experts on Building Materials and Construction Industries, Addis Ababa, July 1979. E/CN.14/HUS/36.

(c) Material substitution and conservation techniques to overcome problems of import dependence and scarcities;

(d) Techniques for converting industrial wastes into useful building materials;

(e) Methods of reducing building costs;

(f) Medium - and small-scale production of building materials;

(g) Reformulation of building codes and regulations.

(iii) Priority areas

21. The following specific research programmes would have a bearing on the priorities outlined above.

(a) Optimization of production

22. In many countries there is underproduction of cement for other than market reasons, for example, because of an inherent imbalance in the condition or quality of raw materials for particular sections of plant and machinery (for example, grinding, grading, drying, sintering etc.) or of an imbalance between the various sections of a plant. Often, plant and equipment are selected in the first place more because of an urgent need to produce cement as quickly as possible than as the result of detailed technical investigations and evaluation of local raw materials for long-term suitability. Also, over the years, the raw material sources originally found suitable may change and the materials from new sources are used unthinkingly. The research centres and the cement factories should get together and organize the basic mineralogical, chemical and mechanical research needed for the introduction of process modifications. The work must be organized on a factory-to-factory basis.

23. There should be research into the upgrading of raw materials quality in countries which are self-sufficient in a particular grade of raw materials. Changes in specifications must also be made where necessary.

24. Kiln refractories should also be investigated and changes suggested where necessary, particularly with reference to thermal properties, refractoriness and mechanical strength, which are critical for cement production.

25. Efficient fuel combustion needs thorough research.

26. The research centre must also deal with machinery performance standards (in particular in the washery, grinding mill and kiln system) and their manpower implications, as two further aspects of productivity.

27. It must research tribology and devise improved techniques of plant maintenance so as to reduce production losses and lengthen plant life.

28. There must also be research into identifying and developing the possible product diversification to ensure full utilization of installed machinery, with additions to existing machinery as required.

29. Similar action should also be taken to increase the production of kilned bricks.

(b) New ways of using traditional materials for improving rural buildings

30. Building activity has been a historic process with a background of accumulated experience, in each country, of using whatever was locally available. At present it is purely an individual enterprise with many limitations, especially in relation to buildings in rural areas. In view of the concentration of population in rural areas, these skills should be strengthened and improved by modern research. The scientific use of agricultural and other wastes and by-products should receive priority in research studies. Some work in this direction is already in progress in the African region but needs to be rationalized.

31. The wastes most common and plentiful are derived from coconut, palm, sugar cane and the stalk and husk of rice and wheat. They are already being used for roofing and wall construction directly or as reinforcement for mud buildings in rural housing. They are extremely flammable and do not withstand heavy rain and wind. Research into simple techniques of impregnating or laminating the materials with fire-resisting chemicals should be encouraged. Pyrene, DF-ammonium phosphate-sodium fluoride mixture 3/, wetting agents etc. have been tried in other regions for rendering the materials fire resistant; water-repellent paints, bitumen and pitch coatings could also be developed.

32. Work is in progress in some African countries on the use of sisal fibre-cement mixtures for the manufacture of roofing slabs and panels 4/. The main problem with this material is its heaviness and the need for special roof supports. The development of light-weight panels will make this material popular for building construction. The use of lime, gypsum and pozzolanic materials for partial replacement of cement could be explored.

33. There are large banana plantations in some countries but very little research has been done on the use of banana fibre as a building material. Its use should be studied in detail with bitumen, gypsum, lime sludge, molasses etc. as bonding agents.

34. The use of banana fibre, bagasse fibre and rice straw for the manufacture of roof and wall panels should be researched.

35. Two important areas for research on vegetable fibres are the blending of strong and weak fibres (a concept applied successfully to textiles) to increase strength, and interaction between building materials research and agricultural research to help identify possible ways of improving crop varieties for improving fibre strength characteristics.

3/ An appropriate technology for low cost rural buildings: Mr. H. C. Mital, Central Building Research Institute, Roorkee, India.

4/ Report of the Second ECA Experts' mission to some African countries (December 1978-January 1979).

36. Groundnut and cashewnut shells and rice husks are ideal filler materials for the manufacture of low-cost boards and slabs for roofing and other purposes, using cement, lime, gypsum and asphalt as bonding agents. Fungus and termite control for rural dwellings should receive high priority in research. Cashewnut shell can very easily be processed into a building varnish providing an effective surface coating against fungus and insect attack and moisture penetration.

37. Rural buildings are usually self-built and the techniques used are manual, time-consuming and do not conform to any standards. Their design and the building materials used vary little. Some of the changes and improvements in construction materials suggested above may require research work on design modifications and building techniques. Adequate norms of natural ventilation, lighting and thermal insulation will have to be determined for the new designs.

38. The concept of self-help in building will continue to be a feature of life in the rural areas. To facilitate the use of new and improved materials and to ease the introduction of quality and performance standards, it will be helpful to design simple manual, easy-to-fabricate and easy-to-use devices for moulding, shaping, pressing, curing and drying building materials.

(c) Substitution and conservation of scarce materials

39. Cement, corrugated galvanized sheet iron and, to a less extent, sheet aluminium are three important building materials which deserve attention because inadequate local production capacities have led to dependence on imports. Countries in the African region spent US$850 million on the import of cement and US$770 on fabricated steel products, including corrugated sheets, in 1977. This level of expenditure is expected to treble by the year 2000. The demand for cement will always be a step ahead of its availability despite substantial increases in production. One reason for this is that its versatility makes it attractive for many purposes, even though alternative materials can be used. Even when basic raw materials required for production of cement, iron sheets and aluminium sheets are readily available (and they are not in many African countries), the lead time for creating new production facilities is at least 5 years for cement and 8 years for steel and aluminium. Besides, they involve heavy investments. (See Annex II and Annex III). The use of these scarce materials must therefore be limited to essential needs.

40. Research on ways of reducing the demand for these materials should cover:

Rationalization of the consumption of cement per unit of construction, where the use of cement is necessary for technical reasons;

The introduction of functionally suitable alternative materials for jobs where the use of cement is not mandatory.

41. The following research is therefore recommended:

(i) A selective study of the specifications for infrastructure projects, urban commercial, public utility and residential buildings and peri-urban dwellings to identify the scope for achieving savings in cement consumption.

(ii) Studies on selected types of construction to identify the scope for the total or partial replacement of cement by other materials;

(iii) Development of lime-pozzolana and clay-pozzolana mixtures as additives or supplements to the cement used in construction; 5/

(iv) Reformulation of construction material specifications in the light of (ii) and (iii);

(v) Development of glass fibre technology to provide a substitute for asbestos fibre in the production of asbestos-cement roofing sheets (asbestos fibre resources are limited and occur only in Zimbabwe and South Africa).

(d) Conversion of industrial wastes

Research is needed on:

(i) the use of the sludge from sugar mills, paper mills, fertilizer plants and non-ferrous metals refining operations for production of a cement mortar substitute;

(ii) the conversion of steel slag waste into slagwool for use as an insulant in large urban commercial buildings;

(iii) the use of pig iron slag waste from blast furnace slag for production of blast furnace slag cement as a substitute for regular portland cement;

(iv) the use of ash from coal-fired industrial and power house boilers to produce fly-ash cement, building bricks and tiles;

(v) the use of wood waste from timber saw mills to produce indoor tiles, slabs and panels.

(e) Methods of reducing construction costs

42. The need for cost reduction (in urban and public constructions) is evident when the magnitude of the current expenditure incurred by the African region is considered. It is presently around US$10 billion per annum and is expected to double by the year 2000. 6/ The achievement of even a 10 per cent saving would be worthwhile. Building materials account for 45-60 per cent of construction costs, labour 20-35 per cent and plant, equipment and overheads 15-25 per cent 7/. Strategies for achieving substantial savings in construction must therefore focus especially on building materials. Also research on the following aspects would help to reduce building costs:

5/ Report of the second ECA Experts' mission to some African countries (December 1978-January 1979).

6/ ECA estimate.

7/ Construction and Building Materials in Africa. E/CN.14/HUS/22.

Wood

The treatment and processing of the less popular timber varieties.

Cement

(i) The upgrading of inferior grades of limestone and dolomite for the production of portland cement;

(ii) The use of lime-rich soils, sea-shells and corals for the production of portland cement;

(iii) The use of waste materials like metal slag, chemical sludge, fly ash and red mud for producing special cements (which also involve lower energy consumption);

(iv) The development of techniques for reducing the temperature and duration of cement clinkering in rotary kilns i.e., reducing both fuel and electricity consumption per unit of cement produced.

Lime

The development of new lime kilns to improve combustion efficiency, increase the yield of lime and achieve uniform quality(at present efficiency is around 60 per cent).

Clay bricks

(i) the design of new continuous brick kilns to increase the yield of mechanically strong first class and second class bricks from its present level of around 50 per cent;

(ii) the introduction of de-airing techniques in the preparation of clay prior to moulding (to achieve the same objective as in (i) above);

(iii) the substitution for fuel oil, which is very costly, of producer gas which can be generated from wood; the use of methane gas produced from agricultural and bio-wastes can also reduce the fuel costs of brick firing.

Construction techniques

(i) The use of dimensional and modular co-ordination in construction; 8/

(ii) Rationalization of the sizes and shapes of materials.

8/ Prefabrication in Africa. E/CN.14/HOU/101.

(f) Medium - and small-scale production of building materials

Cement

43. African Governments have stressed the need to devote attention to production units of small or medium capacity and using local resources 9/. In this context, the following measures are recommended for research.

44. The high cost of internal transport has seriously affected the availability of cement in areas of consumption a long way from cement plants. In some countries the limestone reserves are scattered and no single deposit is large or rich enough to justify the establishment of cement plants of conventional size, for example, 600 tons per day and more. Also, demand points may be scattered. In such circumstances, mini-cement plants (plant size varying from 30 to 100-200 tons per day) may provide the answer. It is reported 10/ that mini-cement plants accounted for a production of 54 million tonnes in the People's Republic of China in 1978 (nearly half the total cement production). A major problem with such plants has been the vertical shaft kiln technology of sintering and its subsequent effect on the quality of the cement produced. The Cement Research Institute of India has reported a breakthrough on this problem as a result of research and pilot studies (2 tons per day) involving the design of a rotary nodule feeder with top feed and a rotary fuel grate 11/. Since there is now sufficient information on the experiences of China and India and large shaft kilns are in operation in some African countries (Algeria 50 000 tonnes per year from 1 kiln; Kenya 700 000 tonnes per year from 6 kilns; Morocco 140 000 tonnes per year from 1 kiln; Zimbabwe 316 000 tonnes per year from 2 kilns; Zaire 280 000 tonnes per year from 4 kilns) 12/, it should be possible for African research institutes to use the existing knowledge to design process systems for small capacities ranging from 30 to 100 tonnes per day.

45. When the points of consumption are scattered and there are long-distance transport problems and difficulties in arranging for bulk storage facilities it is necessary to plan for split production of cement, i.e., producing the clinker at the place where limestone and other infrastructure facilities are located, and grinding the clinker near the points of cement consumption. Since clinker is a hard material, its transport

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9/ Report of the Meeting of African Experts on Building Materials, July 1978; E/CN.14/HUS/24.

10/ 'Small Scale Cement Plants' (Jon Sigurdson), Intermediate Technology Publications, London.

11/, 12/ "Small Scale Cement Plants" (Jon Sigurdson), Intermediate Technology Publications, London.

and storage do not present any major problems. Small cement preparation plants i.e., grinding and finishing sections can then be set up at several points within a country and it may become possible to start up other small-scale activities involving the manufacture of cement-based products. Research institutions will be required to assist in designing suitable equipment.

Clay bricks (burnt)

46. Clay bricks and clay roofing tiles can be produced locally on different scales of plant size according to market needs. The production facilities can also be shifted from one place to another according to the availability of good plastic clays. There is scope for setting up a number of small and medium scale plants using simple machinery for operations like clay preparation, moulding of bricks and tiles and burning them under uniform conditions. Research on raw materials and increasing combustion efficiency can help to improve the quality of the bricks and tiles and would in turn help to reduce cement consumption.

Soil cement blocks

47. Soil cement blocks are good substitutes for sand-cement blocks and burnt clay bricks. Their use helps to reduce the consumption of cement. They do not need fuel for their production and can easily be produced by simple techniques to meet the requirements of urban and rural buildings. They can help substantially to reduce building costs. Research centres can assist in the development of these blocks by undertaking scientific tests and providing information on the suitability of soils.

Ceramics

48. Africa's resources of china clay, fire clay, feldspar and quartz have not yet been researched fully. An important segment of urban building materials viz., sanitary ware and glazed wall and flooring tiles, is based on these materials. Some of the materials can also be used in the production of stoneware pipes for water transport, drainage and sewage to minimize the dependence on cast iron pipes. Small and medium-scale production of these ceramic articles using simple techniques and equipment and kilns of simple designs can be encouraged.

Unburnt building materials

49. Rejects from brick kilns and lime kilns, pumice and other volcanic ash materials and boiler ash are excellent pozzolanic materials which can be converted into unburnt building bricks by combining them with ordinary clay, lime or cement. The composition of mixtures can be standardized and semi-mechanized techniques of small and medium scale production can be used. Sand-lime, laterite-lime, and gypsum-clay products are other possibilities.

(g) Building Codes and Regulations

50. National building codes and regulations need reformulating to take account of the new materials and changes described in this paper so as to be a positive instrument for promoting their use. Existing building codes and regulations are out of touch with the changing conditions in African countries, and so research is needed to bring them into line with African social, economic and cultural conditions.

TRENDS OF CONSUMPTION, PRODUCTION AND IMPORTS OF SELECTED BUILDING MATERIALS IN THE AFRICAN REGION

Material	Unit	1975	1976	1977	1980 *	1985 *	1990 *	1995 *	2000 *
(a) Cement, Lime and Plaster									
Consumption	million tonnes	34.3	34.7	38.2	46.7	68.7	105.3	162.1	250
Production	"	23.4	23.5	25.1	30.7	50.0	88.0	162.0	260
Imports (Net) Qty	"	10.9	11.2	13.1	16.0	18.7	17.3	NIL	NIL
Value	million US$	522.5	532.7	850.3	-	-	-	-	-
(b) Structural steel (rods, bars, sheets, pipes, joints, wire, etc.)									
Consumption	million tonnes	5.0	4.5	4.7	5.7	8.3	13.4	21.6	34.8
Production	"	2.5	2.7	2.9	3.7	5.6	8.9	14.3	35.6
Imports (Net) Qty	"	2.5	1.8	1.8	2.0	2.7	4.5	7.3	NIL
Value	million US$	2,278.6	2,106.1	2,309.0	-	-	-	-	-
(c) Structural clay products									
Consumption	million tonnes	-	15.0	18.0	23.9	38.5	62.0	99.8	160.6
Production	"	-	11.6	13.5	19.2	34.6	62.3	100.3	161.0
Imports (Net) Qty	"	-	3.4	4.5	4.7	3.9	NIL	NIL	NIL
Value	million US$	139.4	101.6	136.6	-	-	-	-	-
(d) Glass									
Consumption	million tonnes	1.7	1.6	2.2	2.9	4.9	8.9	16.0	29.0
Production	"		negligible			2.5	6.6	16.0	29.0
Imports (Net) Qty	"	1.7	1.6	2.2	2.9	2.4	2.3	NIL	NIL
Value	million US$	67.9	63.7	87.4	-	-	-	-	-

1. * ECA estimates.
2. Quantity of imports has been deduced from published value of imports.
3. Source of information for imports: Yearbook of International Trade Statistics, 1978, Vol. II.
4. Source of information for consumption and production. World Statistics in brief. (UN Publication: Sales No.E.78 XVII.9).

Comparative capital investment cost for production of selected building materials

Material	Investment cost (US$ per tonne)	Basis of plant size in arriving at investment cost (tonnes per day)	Cost of material (US$ per tonne)	Source of information
Cement	150	100 (rotary kiln)	72 *	Intermediate technology group London
	200	600 "		- do -
	50	600 "		India
	25	100 (shaft kiln)		India
				* United Rep. of Tanzania
Burnt clay bricks	98	60 (Hoffman kiln)	24	UNIDO
	110	60 (Tunnel kiln)	26	UNIDO
	48	125 (Hoffman kiln)	19	India
Stabilized soil blocks	3 **	-	384 CFA/m^2	Togo (**ECA)
Cement blocks	5 **	-	494 CFA/m^2	Togo (**ECA)
Lime	8 a/	-	17	United Republic of Tanzania (a/ ECA)
Sand-lime bricks	3	-	12	India
Cellular concrete (lime + flyash)	13/m^3	1.7 million m^3	-	India
Lime - pozzolona (Surkhi)	14	20	22	India
Clay - pozzolona	8	20	10	India
Sisal - cement sheet	5 b/	-	2	United Republic of Tanzania (b/ ECA)
Asphalt roofing sheet	0.3/m^2	2 million m^2	1.4/m	India/United Republic of Tanzania
Corrugated Iron sheet	300	-	4.2/m	United Republic of Tanzania
Corrugated Aluminium sheet	300	-	4.93/m	United Rep.of Tanzania
Gypsum plaster	12.4	10 (rotary)	22	India
Sheet glass	50 (Four coult)	40	-	India
	80 (PPG)	40	2	India

Note: 1. Lime-pozzolana can replace up to 40% of portland cement.
2. Clay-pozzolana can replace up to 25% of portland cement.
3. Stabilized soil blocks can replace up to 75% of cement blocks.
4. Corrugated asphalt/sical-cement sheets can replace up to 50% of corrugated iron/aluminium sheets in roofing.
5. Machine-made clay bricks can reduce cement consumption by 10%.

Estimate of investment requirements for additional building materials capacity development

	1980-1985	1985-1990	1990-1995	1995-2000	Total
	(in millions of US dollars) *				
Cement	2000	4560	11100	16600	34260
Structural Steel	600	1155	2160	10650	14565
Sheet Glass	125	307	940	875	2247
Structural Clay products	316	692	1140	2428	4576
Total	3041	6714	15340	30553	55648

(* Cost escalation factor included).