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**APPROPRIATE TECHNOLOGY
FOR THE PRODUCTION OF CEMENT
AND BUILDING MATERIALS**

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APPROPRIATE TECHNOLOGY FOR CEMENT AND BUILDING MATERIALS ,
Discussion Paper

Appropriate Technology for Cement and Building Materials *

Issues and considerations

Note prepared by the secretariat of UNIDO

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Appropriate Technology for Cement and Building Materials

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Introduction

The building materials industry is essentially a complement of the construction industry in general. Its development, therefore, broadly follows the pattern of the construction industry itself and is determined by the construction technology and inputs used, and the character and composition of construction output.

Construction activities in the developing countries can be classified into four broad categories viz. (a) international modern; (b) national modern; (c) national conventional; and (d) traditional. Each category of construction makes a different pattern of demand on the building materials industry. The first two categories of construction throw up demands for sophisticated and costly building materials. In respect of the national conventional and traditional categories of construction, however, the structure of demand is somewhat different and diversified. Demand for building materials for traditional construction is largely conditioned by the suitability and local availability of such materials and displays regional variations depending on climatic conditions. Thus, organic materials like timber, bamboo, reeds, etc., which grow well in warm-humid regions, are used for construction of dwellings in these regions. The hot-dry regions, on the other hand, use inorganic materials like stone, lime, brick, etc. In most of these regions, however, a combination of organic and inorganic materials are used. The national conventional category of construction is found in urban and semi-urban areas. It is based mainly on the traditional methods and materials, which are supplemented with simply formed products derived from the modern industrial sector like corrugated iron sheets for roof, cement as binder, etc.

The major preoccupation of the developing countries in general has hitherto been with the establishment of the basic infrastructure of economic development in terms of basic industries, highways, major townships, massive irrigation projects, airports, bridges, and so on. Such large-scale construction programmes involving application of sophisticated construction techniques necessitated use of sophisticated building materials. These materials were initially imported but subsequently production capacities were developed in varying degrees to

produce them indigenously. The major construction activities in developing countries being concentrated mainly in the modern sectors, the infrastructure for production of these materials has been oriented largely towards more sophisticated items like cement, structural steel, glass, etc. Consequently, the production strategy followed by the developing countries so far, has benefited mainly the modern construction sector comprising large-scale government construction, and private residential constructions by the affluent sections of the urban and rural population, excluding thereby the subsistence sector, hereby depriving the poorer sections almost entirely of the benefits of development of building materials industry because (a) the materials produced in the modern sector are too costly for them; (b) these materials are at variance with the building specifications usually followed by the poorer sections of the population; and (c) of the difficulties in transporting the materials to the rural areas due to poor communication.

The main distinguishing feature between specification of buildings in a subsistence economy, and that in a richer consumer economy is that, in the poorest communities, the materials used are substandard, and therefore life of the structures built by them is too short. Thus, while the affluent sections build houses which last longer and appreciate in value over time, the poorer sections build temporary shelters which need continual repair and restoration.

The problem

It is only recently that the deplorable living conditions of the vast majority of the people living in rural areas and urban slums, have attracted the attention of national governments in developing countries. The quality of the vast majority of rural dwellings in the ESCAP^{1/} region has been described as "usually small, insanitary, often in a dilapidated condition and made of locally available building materials that are flimsy and non-durable. The roofs are very low, and the windows, if provided, are very small and inadequate on account of which rooms are dark and damp". The description can well be extended to slum dwellings in urban areas with the difference that rags, tins and scraps, packing box wood, etc. constitute the building materials used, and the environmental conditions are worse

^{1/} Economic and Social Commission for Asia and the Pacific

due to overcrowding. A World Bank survey of principal cities in 40 developing countries showed that more than half of their population lived in slums and uncontrolled settlements and shanty towns in 28 cities.

The investment and materials required to meet the housing needs of the rural and urban poor would be colossal. The problem is rendered more formidable by the fact that the financial resources of a vast majority of the rural and urban homeless and inadequately housed masses are too meagre even to build modest houses for themselves, while key building materials required to build more durable houses are either not available or are available at prices for which they cannot afford to pay. Growth of population and unchecked migration from the rural areas to the urban centres have added to the dimension and complexity of the problems at both ends.

The factors which have so far inhibited the growth of building materials industries in the developing countries might be classified as follows:

- (a) Absence of an organized sector for production of such materials except cement and structural steel;
- (b) Lack of adequate incentives and assistance for investment in building materials industries;
- (c) Delay in commercialization of the results of R and D and even general apathy for the proven alternative building materials and techniques;
- (d) Problems of transportation, restricting the market for the building materials produced;
- (e) Fluctuations in the building activities of each country, and uncertainty about market;
- (f) Absence of institutional arrangements to study, monitor and deal with physical and financial problems of the small building materials industries;
- (g) Lack of standardization of some of the newer materials and construction techniques which has restricted the size of demand for each category and the building materials produced.

The special problem of rural areas, arising due to difficulties in raising finance needed for vital materials to improve the life of

dwellings, is most conspicuous in the appearance of houses in rural settlements and the fringes of many urban centres in developing countries. Because of the generally poor condition of rural roads, the cost of materials is substantially higher than the price paid by urban dwellers. There is also a scarcity of paid employment in rural areas, a factor which combined with higher costs of conventional materials, makes it considerably more difficult for the rural people to upgrade the quality of their buildings.

Objectives

If the poorer sections of the community have to be helped to build structurally durable and functionally adequate houses, the focus of attention will have to be on the provision of suitable building materials to them at cost they will be able to bear. The materials should be such as are available locally and that do not require much specialized skill in their application in construction.

The objective of any strategy for development of production of building materials for the poor sections of the population should be to provide them with the essential building materials they need at costs convenient to them. The basic purpose of such a strategy should be to enable them to build their dwelling which would serve as (a) a store of value and (b) an appreciating asset so that (i) the time and money they spend in continual maintenance and eventual replacement of their non-durable dwellings would be freed for useful alternative purposes and (ii) the dwelling itself increases in value due to its durability and becomes a capital asset which could be sold or mortgaged if necessary. It is, however, not enough just to make essential building materials available to a subsistent family at reasonable cost. Investment in better materials and physical efforts to improve the durability of dwellings is clearly not worthwhile if the family has no security of tenure of the land on which dwelling would be constructed.

Development of building materials industry in the developing countries has thus an important social dimension or redistributive implication. In any strategy for development of building materials industry, therefore, highest priority would need to be given to the production of materials needed by the poorer sections of the community

for construction of their dwellings. In any evaluation of production technologies, the primary objective should be to encourage production of building materials which are durable and yet cheap and which could be produced locally using locally available raw materials and skills. In devising construction technologies for the poorer communities, the design and specification of the dwellings should broadly correspond to the traditional design and specifications, so that there is no inhibition for the use or adoption of the new designs and specifications or of alternative materials or serious technical difficulties in the application of new materials and techniques involving use of hired skills. It is no solution to suggest better ways of building which require significant cash expenditure because this is one resource which is always in short-supply in a subsistence economy. There are just not enough resources in the world to build dwelling homes for everybody according to the conventional standards, which may cost anything between US\$200 and US\$300 per square metre as against US\$3 to US\$4 per square metre required by the rural and urban fringe communities.

The objective of development of building materials industries to meet the essential needs of the predominant majority of the population in the developing countries, essentially, should be to create availability of the same kind of inputs which are traditionally used by the poorer sections of the community but by modification of the production process and the construction techniques to enable them to build dwellings which would be structurally more durable and functionally more adequate.

Within these parameters, a starting point for assessment of appropriate production technologies would perhaps be to :

- (a) Identify and improve building components whose high performance in constructions would be necessary;
- (b) Identify and develop production of building materials which would need to be considered for qualitative improvement;
- (c) Facilitate greater use of improved building materials which can be locally produced using local skill and materials;
- (d) Encourage, through deliberate policy measures, development of construction technologies which would harmonize (a) with the materials locally produced, and (b) with the skills locally available.

All this is not to suggest that the building material needs of the modern sector should be totally relegated to the background. The imperatives of basic infrastructure development and long-term development needs do call for adequate attention to be given to the development of certain basic materials required in large constructions. But the relative priorities should be so arrayed that the requirements of the subsistence sector, which are of immediate relevance, receive the highest attention of national governments in developing countries. The problem is somewhat simplified by the limited size of the modern sector and the comparatively narrow range of technologies used on the one hand, and by the small number of building types constituting a large percentage of the total construction output.

Technological needs and alternatives

The critical components of dwelling homes required by the poor are the roof, walls and the building frame. Specific attention would need to be given to develop the availability of materials which would improve the durability of these three component parts of the dwelling structures. The building materials required for these three critical components may be categorized as (a) roofing materials; (b) structural materials; and (c) wall materials.

The building materials which deteriorate quickly are generally either organic in origin or mineral in the form of soft stone or unconsolidated soil. Nevertheless, in suitably protected environments, ordinary substances such as wood and dried mud can also last almost indefinitely. The wide differences in durability between the same materials in several situations relates to the configuration and details in building design, or to the use of protective substances to prolong the life of vulnerable components. The problem eases considerably when it is seen as one of obtaining durable surfaces rather than having to make the complete fabric of the building durable. Conventional building technology tends to 'over-engineer' parts of the structure. This is true particularly in the case of the upper sections of partition walls. These are often built of burnt brick or concrete making them internally resistant to impacts of contact with water and biological attacks even though they would not normally be affected by any of them.

A correct understanding of the performance demands of different parts of building will help limit areas of application of the more expensive materials and components, thereby reducing costs. Thus to reduce costs on walls, it should be possible to change the nature of the walls above the 5-foot level and perhaps to use unfired bricks which cost less than half the cost of burnt brick or concrete block. It should also be possible to make unfired brick-walls reasonably impact-resistant by applying a suitable fibrous plaster.

Security of the roof cladding is of critical significance and the task of erecting a durable roof is a constant predicament of the poorer communities. It is important to develop a roof which would last beyond the brief life-cycle of the traditional thatch, and in the process, protect and prolong the life of all other materials within the dwellings. The only example of a locally manufactured roofing product which begins to meet the essential criteria of being durable itself and able to keep the inside of dwelling dry, is the clay tile. Indigenous styles of tiling in significant use include Mangalore tiles in India, and Spanish tiles in Central and South America, and some parts of Africa. The latter and other hand-made products tend to be heavy and accordingly demand complex and timber-consuming roof structures. As a result, the indigenous clay-tiling technology has only prospered in areas where timber has remained plentiful, and cheap. The countries, where timber has increased in relative scarcity and costs, have tended to abandon the use of tiles in low-cost construction. The lighter weight machine-made tiles are generally unsuitable for manufacture in village plants due to the heavy capital costs involved.

Many alternative systems and products have been developed and are in use but none so far developed are able to solve this problem of obtaining durability at a low cost. Asphaltic coir fibre cement sheets etc., which have a longer life as compared to traditional materials like thatch, cost almost half that of AC sheets, are still too costly for the poor.

Highly mechanized brick plants have not proved very successful in many countries on account of lack of sustained demand, heavy investment, high cost of transportation etc. These have largely catered to large-scale localized demands of urban areas and have not benefited the poorer sections in either rural or urban areas. It is essential to develop small labour-intensive brick plants to meet local demands in rural or semi-urban areas using locally available soils for production of bricks of reasonably good quality at low cost. In this connexion the techno-economic aspects of the semi-mechanized brick plant developed by the Central Building Research Institute, Roorkee, India, might be further investigated for widespread use in developing countries. Sand-lime bricks, lime-silica cellular concrete, etc. are also extensively used in the Federal Republic of Germany, Poland, USSR, U.K. etc. While such bricks may be ideal in many parts of West and South East Asia, the capital cost of the technology is very high. Nevertheless, the possibility of scaling down the size of the plants now available and also of simplification of some of the processes involved might be investigated.

Use of cementitious materials is indispensable in any construction. Most of the developing countries have established or have plans to establish large-scale cement plants. However, the high costs of modern cement plants and the scattered and decentralized demand for cement requiring transportation under uncharitable conditions, and also the need for conservation of cement for essential construction in which its substitution is neither technically feasible nor economically viable, call for production of alternative cementitious materials for use by the poorer sections of the population. Technologies developed for establishment of mini-cement plants would need to be carefully evaluated and investigated for their techno-economic viability. Technologies have been developed for masonry cement made from a mixture of waste lime sludge from sugar and paper mills and cement, rapid setting lime pozzolana mortar and plasters based on lime kiln rejects and locally available ashes, lime sludge and rice-husk cementations material and rice-husk pozzolanic material, which can be a suitable binder for rice-producing areas. Almost any pozzolanic material such as fly-ash, cinder, burnt clay, kiln ashes, fuel ashes, rice-husk ash, etc. can be used to prepare lime-based mortars which might be safely used for low-cost residential constructions.

To economize in the use of scarce and costly Portland cement, feasibilities of use of more and more blended cements such as portland pozzolana cement, portland fly ash cement, and portland blast furnace slag cement should be explored. Mines and mineral processing industries throw out enormous quantities of fine siliceous and dolomitic wastes. These wastes can be utilized in making masonry mortars, flooring tiles, etc. Siliceous lime stone rejects, on burning, give semi-hydraulic lime. The slate mine rejects and lime stone nodules can be a good hydraulic binder.

Bamboo and wood are extensively used in developing countries in all the basic components as well as fittings and fixtures of dwelling structures constructed by the poorer sections of the population and will continue to be indispensable for such purposes. However, due to their biological origin, bamboo and wood deteriorate quickly entailing constant repair of dwellings constructed using these materials. There are specialized techniques of using bamboo and wood all over the world. Use of bamboo and wood as reinforcement in cement concrete or in conjunction with lime pozzolana mortar can be propagated for construction of cheap and durable structural frames for simpler dwellings. Pretreatment of bamboo and wood against moisture swelling, decay and termite attack can considerably improve the durability of these materials used on construction of dwelling houses.

In most developing countries timber is costly and first-class timber is beyond the reach of the poorer sections of the community while the secondary species of timber deteriorate quickly and need frequent replacement. The solar seasoning kiln developed in India for seasoning of timber can be used for the seasoning of secondary species of timber to improve their durability. Pretreatment of timber used in the building components or fittings and fixtures can considerably increase their durability and consequently of the dwellings constructed using such timber.

Various technological alternatives for production building materials have been discussed in detail in the background papers. However, more specific consideration is needed on the alternative technologies for the production of cement and cement alternatives, bricks and structural materials particularly those using bamboo and wood.

Appropriate construction and planning techniques

There is considerable scope for bringing about improvement in the conventional construction techniques which would minimize the use of expensive materials like cement and steel without affecting the quality of construction output.

There are several components of the conventional building structures where, usually, more expensive building materials are used than are actually needed. The tendency to 'over-engineer' is more common in the conventional modern constructions. The techniques used in urban areas mostly utilize costly and scarce building materials, without any attempt to utilize locally available material resources. The rural houses are constructed with local materials without any attempt to improve their quality or to make them more durable. Thus the former is wasteful and the latter is substandard.

Techniques have been developed for economizing in foundation work, walling specifications, doors and windows, building frames, roofing and flooring by use of either alternative building materials or by varying the conventional specifications. The objective is to reduce the cost of construction without detracting from the durability of the structures. Some of these techniques have been discussed in detail in the background papers. Suitability of construction techniques in the special circumstances of the developing countries, will however, depend largely on their linkages with the locally available materials and skills, their employment potentialities, the saving they facilitate in the use of scarce and costly materials as well as of time involved in construction.

R and D

There is a serious anxiety in the developing countries to improve the housing conditions of the poorer sections of the populations. Considerable R and D work has been done in a number of developing countries to improve the quality of building materials traditionally used for construction of dwellings by the poor as well as of the techniques followed in such construction. However, since the problem is so vast and since the needs are so divergent due to regional variations in construction practices as well as of materials available locally and used, much more needs to be done to create the necessary impact. The problems of the subsistence sector in the rural areas would need particular attention on account of

their special circumstances requiring maximum possible use of local raw materials and skill. The objective of R and D in this respect should be to promote establishment of building material production capacities in the rural areas not only to ensure local availability of such materials but also to create employment opportunities in rural areas. The national R and D programmes may be aimed at:

- (a) Developing suitable building materials from locally available raw materials hitherto unutilized including agricultural, industrial and forest wastes;
- (b) Improving the durability of traditional building materials by making suitable modifications in the composition of raw materials or by modification of manufacturing processes;
- (c) Evolving new construction techniques with a view to economizing in the cost of construction as well as in consumption of building materials by optimum utilization of their strength;
- (d) Evolving new building techniques to improve speed + cost of construction.

The R and D agencies involved in the work should maintain close and constant liaison with the producer of new building materials and components on the one hand, and with the users of such materials on the other, in order to evaluate the performance of such new materials. There should be adequate interlinkage also between research institutions and educational institutions, so that the teaching curricula of the latter include the uses and application of new building materials and techniques. Social institutions should be closely involved in the field testing of new building materials and techniques evolved as well as in the demonstration of these materials and techniques for their better extension effect.

Above all, the national governments should not only promote extensive R and D work in alternative building materials and construction techniques, but they should themselves adopt the proven results of R and D in these respects in their own construction programmes.

There is still a considerable gap in R and D work in the respect of alternative cheap roofing materials, cheaper brick-making techniques in the small scale, using locally available clay, as also in small-scale production of Portland cement. More R and D work is indicated for improving the techniques for seasoning of timber and its use in structural reinforcement. Background papers of the Forum deal with some of these aspects.

There is considerable scope for co-operation and interaction among developing countries in the field of R and D. Since the problem of housing of the poor now faced by these countries is qualitatively the same everywhere, there is much to gain by international co-operation in R and D in this field and even more so because the materials used in the subsistent sector in these countries for construction of dwellings are more or less similar in character and origin. Even the traditional construction techniques in the subsistence sector in many of the developing countries are substantially the same.

Significant R and D work has been done in a number of developing countries in improving the quality of building materials traditionally used by the poor in construction of dwellings. International exchange of information about these achievements will be mutually beneficial to the developing countries. International agencies like UNDO and HABITAT can help in establishing a data bank on the new building materials and techniques developed in some of the developing countries, and also facilitate exchange of technical information as well as experts between these countries. They can also assist in establishment of regional research centres for undertaking expanded R and D work on specific building materials and techniques which might be of relevance to a number of developing countries in the region.

Policy implications

Development of production of building materials needed by the poorer sections of the population in developing countries has significant social and redistributive implications. The rich using costly and sophisticated building materials construct permanent buildings which are not only a store of value for them, but also an appreciating asset while the poor, using flimsy materials, construct dwellings which are a continuous liability for them in that their dwellings require constant

repair. Thus, left to themselves, the richer sections gain by investing in building, while the poor have no real solution in sight.

The strategy for development of building materials industries in developing countries must, therefore, be oriented towards production of such materials as the poor would need to build durable dwellings for themselves at costs they can bear to pay. Production of such building materials can be best developed on a decentralized basis through a policy featuring provision of fiscal and monetary incentives and support in production and sustained government assistance in the marketing of materials produced. In the social construction sector, governments themselves should use, as far as possible, materials produced in the decentralized sector instead of using, as at present, conventional building materials. This will encourage extensive production of alternative building materials by expanding the demand-base in respect of such materials. Production of non-conventional building materials may be left to the private entrepreneurs in the decentralized sector to (a) ensure maximum use of locally available raw materials; (b) create employment opportunities in the rural areas; (c) avoid long transportation of building materials which increase the delivery price of such materials. The government should, however, mitigate the risks of the scattered small entrepreneurs producing building materials by (a) assisting procurement of inputs like fuel, cement, sand, etc., and (b) guaranteed purchase of a portion of their production. The fledgling small-scale building materials industry would need to be assisted with subsidies and incentives and technical guidance through informal agencies until they are able to be profitable. .

Programme of action

The programme of action at the national level may comprise of the following elements:

- (a) Identification of the building materials traditionally used by the poorer sections of the population in construction of dwelling houses so as to initiate a rational R and D programme in respect of these materials;

- (b) Promote, through incentives and subsidies, the production of improved traditional building materials in decentralized private undertakings;
- (c) Extensive use of alternative building materials developed through R and D in government construction programmes where the conventional building material can be substituted without impairing unduly the quality of the construction output;
- (d) Dissemination of information about alternative building materials and techniques developed for construction of cheaper dwellings;
- (e) Establishment of appropriate financial institutions exclusively to assist through liberal and subsidized loans assistance, the establishment of new enterprises in the decentralized sector for production of improved traditional and non-conventional building materials;
- (f) Guaranteed purchase of a part of the production of improved traditional and non-conventional materials produced in the decentralized sector by the government agencies;
- (g) Guaranteed supply of scarce raw materials at reasonable prices to the decentralized undertakings producing building materials required for subsistent enterprises;
- (h) Centralized import of new technologies developed in other countries for production of cheaper alternative building materials for dissemination within the country;
- (i) Strengthening of the existing R and D structure to take on the expanded responsibility of developing alternative building materials as well as of improving the quality of traditional materials;
- (j) Establishment of rural technology centres in the rural areas to provide technical guidance in production as well as in application of new building materials and techniques.

At the international level, the programme of work which can be taken up by UNIDO's Industrial and Technological Information Bank (INTIB) and other international agencies, i.e. HABITAT may comprise of

1. A comprehensive data bank on the new technologies and processes that have been developed for the production of improved traditional materials and cheaper alternative materials as well as of the alternative construction techniques for effecting economies in the use of building materials in construction;

2. Assist in exchange of technical information between developed and developing countries and among developing countries themselves through establishment of regional research and development centres having technical linkages with the national institutions;
3. Assist in transfer of technologies for the production of cheaper alternative building materials among developing countries;
4. Organize training facilities for technical personnel in developing countries in planning and execution of production programmes as well as new construction techniques developed in other developing countries;
5. Participate, financially as well as technically, in specific R and D projects which might be of relevance and interest to a number of developing countries;
6. Organize seminars, expert group meetings etc. to deliberate on and discuss common problems and to exchange experiences in the field of development, production and application of alternative building materials and techniques.

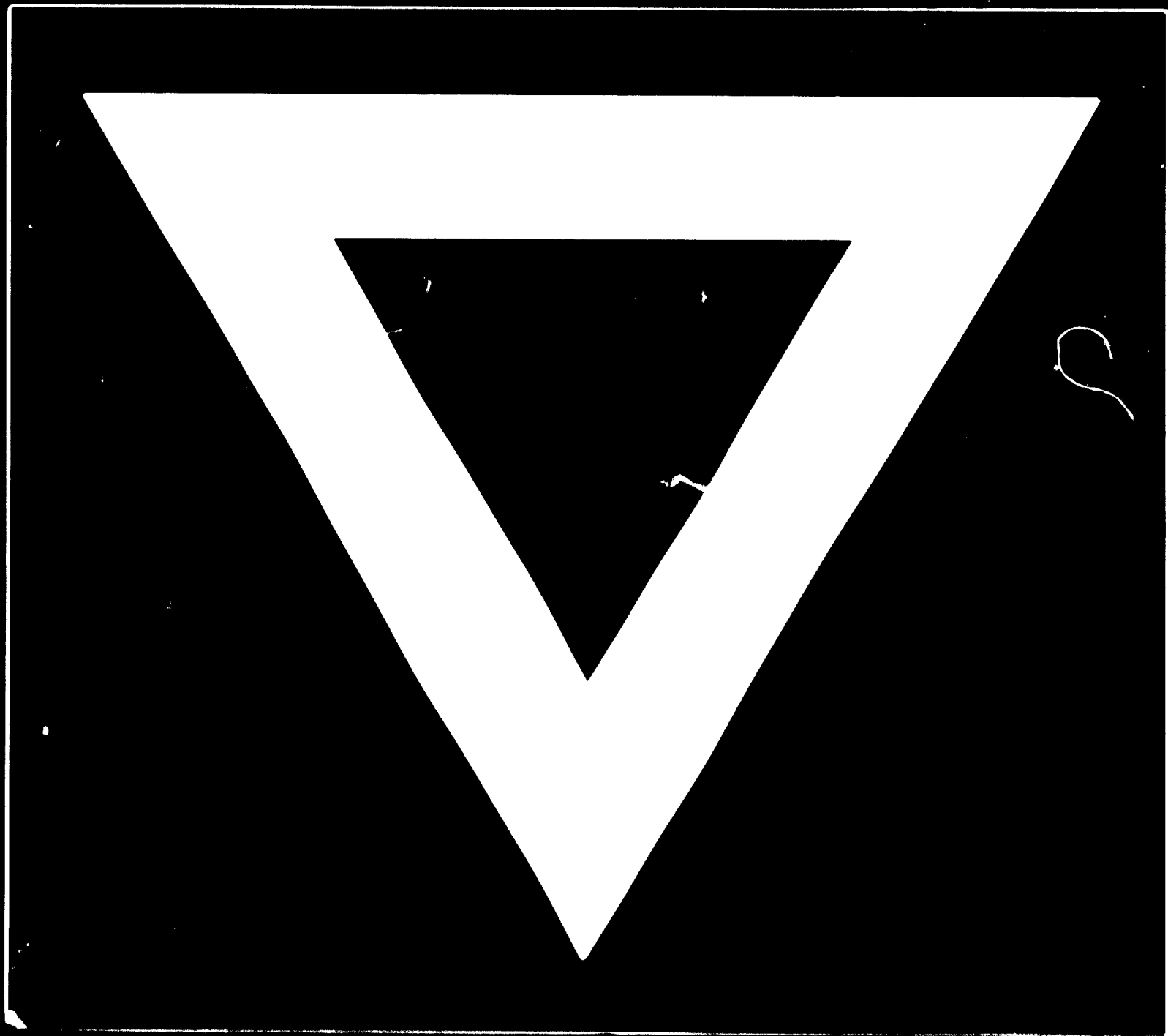
The following background documents are being circulated on this subject:

Strategies for Development of Cement and Allied Industries in Developing Countries	ID/WG.282/2
Sisal Fibre Concrete for Roofing Sheets and Other Purposes	ID/WG.282/11 + Corr.1
Appropriate Technology and Materials for Housing and Building	ID/WG.282/30
Construction and Building Materials Industry in Nepal	ID/WG.282/35
Project Proposal and Feasibility Data for a 25 ton/day Mini-Cement Plant	ID/WG.282/33
Opportunities for Technical Co-operation between Developing Countries for Producing Building Materials	ID/WG.282/49
Building Materials and Components	ID/WG.282/56
Construction and Building Materials Industry in United Republic of Cameroon	ID/WG.282/57
Appropriate Technology in the Construction and Building Materials Industry	ID/WG.282/58
Choice of Appropriate Construction Technology in the Building Industry in Iran	ID/WG.282/60
The Role of National Institutions and Raw Materials Problems in Building Materials Industries	ID/WG.282/71
Case Study of Building Materials and Building Techniques for Rural Areas	ID/WG.282/82
Appropriate Technologies for Small-Scale Production of Cement and Cementitious Materials	ID/WG.282/92
Mechanization of Construction and Choice of Appropriate Technology in Civil Engineering	ID/WG.282/78

ID/WG.282/104
ID/WG.282/108



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