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APPROPRIATE TECHNOLOGY FOR THE PRODUCTION OF CEMENT AND BUILDING MATERIALS

APPROPRIATE TECHNOLOGIES AND MATERIALS FOR HOUSING AND BUILDING

Background Paper

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APPROPRIATE TECHNOLOGIES AND MATERIALS FOR HOUSING AND BUILDING

by

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CONTENTS

SUMMARY AND CONCLUSIONS

: : Building are of primary importance to a country, whether they are meant for housing or for carrying out other activities for satisfying human needs.

: The developing countries have got a highly insufficient building stock with them for satisfactory performance of the activities in various fields, and particularly shelter to all of their citizens. It is, therefore, the most pressing need to construct more and more houses to cover the present acute shortage and to cater for future needs.

: For fulfilling this goal sufficient resources are needed by way of money and materials, which are not available at present, nor are likely to be there in the foreseeable future.

: This calls for development of appropriate technology and materials. This would result in cost reduction and conservation of scarce building materials. It will also result in evolving new techniques resulting in less consumption of materials and utilizing indigen-ous skill and labour which is available in plenty in developing countries.

: More attention should, therefore, be paid to R&D activities for evolving appropriate technology and materials.

: Hence more funds should be provided to pursue R&D activities in this field.

: Large scale dissemination of information regarding the available appropriate technology will be required for which all possible means such as news, and other mass media should be used.

: Incentives should be provided for production and use of cost saving materials and techniques by way of tax reduction, financial assistance at lower interest rates etc.

: Higher priorities for production of building materials are required to be given in National Plans which should be one step ahead of the National Plans for development and construction.

: Housing and Building Industry should be included in the core sector of the National plans.

: Adequate training of craftsmen, engineers, entrepreneur will be essential in use and production of new materials and will have to be arranged as a part of national policy. To popularise it, incentives will have to be given.

: It may be necessary to ban the misuse of building materials by suitable legislation.

: Lime and brick making industries should be given a special status and high priority.

: Research for improving quality of bricks should be intensified.

: Appropriate technology for rural areas should be developed and suitable measures for its large scale adoption taken to make it popular.

: Large scale tree and bamboo plantation should be implemented to increase and renew these two natural resources which provide important building materials specially for rural areas.

- Planning of buildings should be rationalised and standards fixed on the basis of needs and resources, subject to their being amenable to changes, improvements and modifications, to suit the changing needs, and affordability of the users.

- Latest management techniques should be used to enable implementation of schemes in minimum time and least wastage of human and material resources.

- The building construction and material production techniques should be labour intensive so as to provide employment to the large labour force available in most developing countries. This will also need decentralization of Building Industry and locating them nearer to the rural areas and small towns.

- It is necessary to take measures to motivate people to mobilise their savings for house construction. This can be done by making developed sites available to them at a reasonable price.

- In all government programmes of large scale building construction, suitable building materials and techniques developed by the research institutes should be adopted as much as possible.

- The building codes and bye-laws as existing to-day should be modified so that they help the adoption of appropriate technology.

- Active cooperation and mutual exchange of ideas with other developing countries should be encouraged.

- The motto of building construction and material industry should be "the maximum benefit to the maximum numbers".

INTRODUCTION

0.1. The three primary necessities of man from time immemorial have been food, clothing and shelter. Though the advancement of civilization has resulted in many changes in the shape of these necessities, yet their basic character remains the same. Social changes, industrialization, religion and the way of living, geographical location and political climates have all had an influence on these prime needs.

0.2. Out of these three prime needs, shelter comes last. This is not surprising, as a human being has to have food and clothing first, to survive. As observed by the Planning Commission of India in its Draft 5 year plan (1974-79), "a large proportion of the population has to go without even the most essential needs of daily life, because total national income, and hence the aggregate consumption, is too small relatively to the enormous size of population and, secondly, the distribution of this income is very uneven." This applies more or less to all developing countries. When the majority of the population lives below or just at the verge of poverty line, they have to spend as much as 80% of their total income on food alone. Whatever is left is hardly sufficient for their needs for clothing and other petty needs and almost nothing is left for shelters.

0.3. The most neglected and the least satisfactory area of human needs is the provision of suitable shelter in a congenial environment. The quality of the vast majority of rural dwellings in the ESCAP 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 windows, if provided, are small and inadequate, on account of which rooms are dark and damp."* The description can well be extended to the slum dwellings in urban areas with the difference that gunny rags, tins and scrap, wooden pieces from packing cases etc., form the building materials and the environmental conditions are far worse due to over-crowdings and poor, undeveloped or even low lying land sites. A World Bank Survey of principal cities in forty developing countries showed that more than half of their population lived in slums and uncontrolled settlements in seventeen cities, between a third and half in 11 cities and the remaining 12 cities had less than a third of the population living in slums and squatter settlements. In a survey of Kanpur (India) the total slum population is stated to have increased from 2,42,750 in 1961 to 5,60,000 in 1976. 57.5 percent of the households had only one room and another 25.7 percent 2 rooms. 75.4 percent of the houses had no windows and 80 percent no latrines and 66.3 percent experinced water-logging during rains. Similar conditions or even worse could be cited for many more cities.

0.3.1. Two factors are responsible for this state of things:-

(a). Cities and metropolitan areas have been growing too fast and it has been impossible to construct houses and other services even to meet the existing backlogs to say nothing of the growing demand.

(b). 60 to 70% of the urban people cannot afford to pay for even a minimum house with approx 20 sq. metres of floor area.

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* Economic & Social Commission for Asia and Pacific-Survey of Rural Housing and related Community facilities in Developing Countries of the Escap Region - Dec. 1976 pp. 8.

0.4. An ESCAP Survey gives the following estimates of housing needs for Asia:-

Estimated Housing Needs, Asia, 1970-1975
(million)

Need arising from	1970-1975 Urban	1970-1975 Rural	1975-1980 Urban	1975-1980 Rural	1980-1985 Urban	1980-1985 Rural
New Households	4.88	4.71	5.76	4.69	10.68	4.55
Replacement	2.03	7.04	2.03	7.04	2.03	7.04
1970 backlog	1.35	4.69	1.35	4.69	1.35	4.69
	8.26	16.44	9.14	16.42	14.06	16.28

0.4.1. In a study made by N.B.O.*, it has been reported that in India alone the housing shortage (as per 1971 census) comes to 11.6 million in rural areas and 2.9 million in urban areas. The projected figures for 1974 are 11.8 million in rural areas and 3.8 million for the urban areas totalling to 15.6 million houses. If projected further, the figures for 1977 would be 12.1 million for rural and 4.7 million for urban the total being 16.8 million houses. Assuming an average modest cost of Rs.3000 for a rural house and Rs.12000 for an urban house, the financial requirement works out to Rs.9270 crores which is an extra-ordinary sum for any Government to provide.

0.4.2. The following table gives the number of persons per room living in various sized houses:-

* Report of Development Group on low cost housing including Min. Eco. specifications, P-13-14-19-20.

CONGESTION IN HOUSES

Size of household	Percentage of Population					
	Total		Urban		Rural	
	1961	1971	1961	1971	1961	1971
One roomed	41.33	47.81	46.81	50.13	40.86	47.24
Two roomed	26.98	28.17	24.93	26.97	27.16	28.46
Three roomed	13.25	12.00	11.69	11.44	13.40	12.13
Four roomed	7.64	5.98	6.75	5.72	7.72	6.04
Five roomed	9.50	5.94	9.16	5.64	9.45	6.02

Sources : (i). Indian Census through a hundred years

(ii). Census in India - 1971

Series I - India

Part IV B Housing tables

It would be seen from this table that approximately three-fourths of the population are either living in one-roomed or two-roomed houses. The average number of rooms in a dwelling in India is only 2.02.

0.5. From the above facts, the enormity of the problem can be well realized. The investment and materials required to meet this housing shortage are colossal. The financial resources of a majority of the houseless or inadequately housed masses are too meagre to build even a modest house for themselves. The affluent section of society is not interested in mass housing as the returns by way of rental are poor. Obviously the responsibilities for providing houses for those sections of the society falls on the public agencies. The possibility of finding resources to undertake the housing programme on a mass scale has been explored from time to time, but it has not been possible to mobilise sufficient funds for the purpose.

0.6. Financial constraints are not the only hinderance in the way of mass housing. Another very important factor is the scarcity of key building materials. Realizing its importance, the Working Group on Building Materials, Manpower and Construction Technology for the fifth five year plan of India laid down the following targets for the Building Material Industry:

	Availability in 1974-75	Requirements in 1978-79	Per annum compound rate of growth visualised (%)
Brick (Million Nos.)	24,000	37,500	11.80
Cement (Million tonnes)	18.00	27.00	10.70
Steel (Million tonnes)	4.00	6.90	14.60
Timber (Million cu.mt.)	2.00	4.00	19.00

Source : Agenda for Conference of State Ministers of Housing and Urban Development - Calcutta, Dec. 1976 - P.104.

0.6.1. Inspite of special stress having been laid for the production and use of local materials, working of Building Industry in the first 2½ years of the fifth plan has shown that it continued to face problems of the same dimensions and scale as in the past. Further, the housing agencies continued to face a variety of problems relating to erratic supply of building materials and that, too, of indifferent quality. In the absence of any significant improvement in the productivity and expansion of Building Material Industries, the discouraging trends have set in manifesting themselves to the rising prices of key building materials and rising construction costs.

0.6.2. The following factors can be broadly classified inhibiting the growth of building material industry in India:-

(i). Absence of an organised sector except for cement and steel.

(ii). Lack of adequate incentive for investment in building material industries.

(iii). Delay in making use of the results of research and development and even under-utilisation of proven building techniques. There are no agencies at the Central or the State level which make a concerted effort either to translate the research findings into commercial/industrial schemes or promote the use of local, cheaper or substitute materials or rationalised use of building materials.

(iv). Want of legislation prohibiting misuse of materials.

(v). Scarcity of fuel i.e. coal and power.

(vi). Transport problems restricting the area of use.

(vii). Wide fluctuations in the building activity in the country and uncertainty about market.

(viii). Want of effort on an appropriate scale to prove the techno-economic feasibility of some of the new products and processes.

(ix). Want of an institutional arrangement to study, monitor and solve the physical and financial problems of the small building material industries.

(x). Lack of standardisation in some newer materials.

0.6.3. The building construction activity has greatly suffered due to all these constraints. In addition a few more constraints have inhibited its growth:

: Non-availability of land at economic prices.

: Delay in land acquisition.

: Management problems.

: Lack of sufficient technical personnel and skilled labour.

: Lack of knowledge about the latest materials and techniques developed by the research institutions.

0.6.4. Unless all these constraints are overcome by an all round effort, the position will go on progressively deteriorating. Violence and Civil upheaval may be the penalty inflicted on the society by the poor, for their being deprived of one of the basic human needs i.e. housing.

0.7. A number of efforts have been made by Government of India and various public organisations to overcome the problem of housing shortage. Some of these are:

: Bank Finance on Housing Schemes at Low rate of interest, particularly for the economically weaker section of society.

: Differential rates of interest on loans advanced to beneficiaries under social housing schemes.

: Co-operative Housing & allocation of larger LIC funds for the same.

: Establishment of various housing agencies all over the country such as Housing Boards, Development Authorities, Rural and Harijan Housing Boards, Apex Co-operative Federations etc. to promote housing activities and to make available cheap houses to public at a low rate of interest.

: Housing schemes for industrial workers.

: Provision of housing facilities to aged and old persons, working women, and retired or retiring Government servants.

: Scheme for provision of house sites to landless workers in rural areas.

: Provision of funds in fifth five year plan for production of new building materials.

: Establishment of public sector undertakings for the production of such materials.

: Promotion of research and development of new building materials and techniques by providing funds to institutions like CBRI and SERC.

: Operating an experimental housing scheme by the N.B.O.

: Legislation on Urban Land Ceiling.

: Central scheme for integrated urban development in Metropolitan cities and areas of National Importance.

: Scheme for slum clearance and slum improvement, with shift of emphasis from the former to the latter.

: Setting up of a Housing & Urban Development Corporation (HUDCO) for financing Housing Schemes, both for Rural and urban areas and also for setting up of building industries.

: Planning legislation by States and preparation of Master plans for cities.

0.7.1. Inspite of all these efforts, the housing shortage continues to be acute. The reasons are not far to seek. The unprecendented growth of population, the unchecked migration from the rural to the urban areas and the increase in the number of landless labourers, have far outpaced the overall increase in the housing stock of the country. It is, therefore, obvious that something more is needed.

0.8. In order that the available resources may be utilised best, it is essential that "Greatest Benefit to the greatest number" should be the motto of the housing and building policy. For achieving this objective, it is necessary to adopt such building materials and construction techniques as will minimise the use of scarce national resources like capital, energy and transportation systems and will generate more employment. For this it is essential,

: to evolve cheaper building materials, utilizing locally available raw materials.

: to evolve cheaper and time saving building construction techniques.

: to ensure that both the new materials and new techniques should be labour intensive, particularly in India and other developing countries where manpower is available in plenty.

: To evolve appropriate planning techniques and house plans at the cheapest cost, without sacrifying the minimum basic requirements of the users.

: to educate the profession and the industry in the production and use of these materials and techniques.

0.8.1. The building material industry plays a key role in achievement of the economic and social objectives of a country. Over half of the total plan investment in the fifth plan was to be spent on construction alone. Over 60% of the total money in the construction sector alone was, consequently, to be invested on building materials and components. Improvement in the capacity and productivity of building material industry could therefore result in large scale benefits through cost reduction and could even improve capital output ratio of other industries.

0.8.2. It will be of great benefit to the overall building construction activity if the industry could be taken to rural areas. The benefits obtained from the same are enumerated below:

(a). It will be easy to utilize locally available raw materials at low cost.

(b). Expenditure in transportation of materials to great distances would be avoided if small scale industries are established in the vicinity of construction activity.

(c). It will provide incentive to the rural enterpreneur, with low capital, resulting in providing job opportunities at home, which will check the migration from rural areas.

0.8.3. It can be expected that all these measures will result in:

: cost reduction of buildings,

: large availability of suitable materials at cheaper rates,

: an overall improvement in the quality of life for the rural and urban poor by providing him with job opportunities as well as a house that he can afford.

0.9. A lot has been done in India so far towards achieving the above goal, details of which are given in the forthcoming chapters.

Chapter - I

1.0. IDENTIFICATION AND GROUPING OF TRADITIONAL BUILDING CONSTRUCTION TECHNIQUES

1.1. These techniques can be broadly grouped under 2 headings viz. suitable for urban buildings and suitable for rural buildings.

1.1.1. Urban buildings can again be grouped in two categories.

1.1.1.1. High and middle class residential buildings and other general buildings including offices, schools, hospitals, recreational buildings, factory buildings, marketing centres etc. The main criteria in adopting the various techniques for these buildings has been about their strength and appearance with little regard to the cost. Availability of materials has also played an important part in selecting the suitable techniques, which are listed below:

- Raft, pile or open foundation of R.C.C.
- Spread footings in brick masonry and lime concrete.
- Coarse or random rouble stone masonry.
- Brick masonry in cement or lime mortar for foundation and super structure.
- RCC columns, beams and lintels or RCC framed structure.
- RCC roofs laid in-situ.
- R.B. roofs laid in-situ.
- Lime concrete or mud-phuska in roof terracing.
- Cement plaster in walls and ceilings.

- Plain C.C. or mosaic or tile floors.
- Water proof cement paints and distempers or simple white and colour wash.
- Glazed sanitary and water supply fittings served by G.I. pipes.
- Flush or panelled door shutters of teak wood or other decorative or plain woods.
- Sal wood or rolled steel section door frames.
- Brass, aluminium or oxidised iron fittings for doors and windows.
- Glazed superior quality wooden or steel windows.
- ACC or G.I. sheet roofing.
- Terrasso floors and wall facings.
- Etc., etc.

1.1.1.2. Low Cost Houses - Till recently no special materials were evolved for such buildings and only the cheaper materials of the above enumerated traditional building materials and techniques were being used in them. Only minor changes were made by providing the low cost houses with plain C.C. or brick floors, finishing the walls with white or colour wash and using inferior quality of door/window shutters, with iron fittings, and also slightly inferior water supply and sanitary fittings.

1.1.2. Rural Buildings - These can also be grouped in two categories.

1.1.2.1. Permanent Structures - These include Pukka houses with RCC or RB roofs, which, sometimes, may have A.C. or G.I. sheet roofing. In other aspects the specifications are practically the same as for low cost urban houses. The rich farmers and land owners do construct houses with costlier materials and techniques also, but their number is very limited. Basically the main difference between the costlier and cheaper permanent buildings in villagesis in the thickness of walls, heights of buildings and number of storeys in the buildings (the costlier buildings are generally 2 or 3 storeyed while the others are single storeyed). Another difference is in the finishing items and door and window shutters and fittings.

1.1.2.2. Kuccha (Perishable) Structures - The bulk of rural construction, particularly houses, all over India and in other developing countries too come under this category. The general specifications of these houses vary from place to place depending on the local availability of building materials. The main specifications generally are:

(a). Foundations

Compacted brick or stone ballast with or without lime mortar and sometimes using only mud as a binding material. Over this, burnt or sun dried brick-work is used. In still cheaper buildings, only rammed earth foundations are provided.

(b). Super Structure

This is made with mud or sun dried bricks, sometimes using burnt bricks also, partially or fully, mostly without any plaster either inside or outside.

Another type of super structure is made by bally or bamboo frames eliminating the foundations for walling. The walling is provided by thatch, palmyrah leaves, reeds or split bamboo jafry, plastered with mud and cow dung on both sides or protected only by gunny bags or thatch. No lintels are needed for such walling and shutters can also be provided of the same material. If mud or masonry walls are used, lintels are provided by ballies, bamboos or planks of secondary species of timber.

(c). Roofs

These are generally sloping provided with bamboo/bally frames covered by country tiles, slates, wooden planks, palmyrah leaves, thatch etc. Sometimes flat roofs are made by country wood rafters, spanned by bamboo, wooden planks, reeds etc. which is again covered by rammed earth.

(d). Services

Generally no electricity, water supply or sanitary services are provided. In most cases a hand pump or an open well serves as the source of water supply to a group of houses, while open fields or conservancy type latrines are used for attending to the call of nature.

(e). Finishing

Finishing is done both for floors and walling by mud plaster covered with cow dung rendering. Sometimes floors are provided in burnt bricks, which may also be plastered with cement mortar, if the house-holder can afford the cost.

1.2. Regional Variations

These general patterns, both in permanent and perishable structures, vary from place to place, depending on:

- Local materials.
- Available skill.
- Cultural and traditional values.
- Social systems.
- Climate.

It will be observed that while the techniques used in urban areas mostly utilize costly and scarce building materials, without any attempt to utilise 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 other is substandard. Hence, the need for appropriate technology to remove this anomaly.

Chapter - II

2.0. GENERAL OUTLOOK ON BUILDING CONST. IN DEVELOPING COUNTRIES

2.1. The general outlook on design of buildings is effected not only by the traditional values but also by a number of other factors such as:

: Socio-economic changes in the society.

: Rising level of affluence.

: Impact of alround progress in the country.

: Impact of education.

2.1.1. All these factors result in increased awareness, which heightens the ambitions of the masses on the one hand, but also makes them more adaptable to new ideas, materials and techniques. Their level of acceptability, needs and standards also changes. All these factors have to be kept in view while developing the appropriate technology, both for rural and urban areas.

2.2. <u>Present Trends in Building Construction and their Standards</u>

The acute shortage of housing stock at present is being felt keenly both by the Government and the public. All round efforts have been made by the Government of India, the State Governments and various semi-Government and private organisations to overcome this problem of housing shortage. Some of the steps taken have already been enumerated earlier.

2.2.1. It is heartening to note that now it is being realised by the Government and other agencies involved in building construction, particularly in the field of housing, that, in view of the limitation of our resources, the cost of construction should be reduced as much as possible. There is an erroneous impression in the minds of some people that reduction in the cost of buildings also results in making them unsafe, unstable or substandard. Actually it is not so, and it is heartening to note that more and more people are now getting converted to the idea that they can construct structurally safe and functionally sound buildings at a lesser cost by adopting suitable cost reduction techniques and materials. It is also being realised that even with traditional materials, the cost can be reduced by proper planning and selection of suitable specifications.

2.3. This changed outlook towards economy in building construction has naturally focussed the attention on modification in the standards also. So far, the practice had been to fix the standards on the basis of ideas borrowed from affluent developed countries. However, it is being increasingly realised now that the standards fixed for any activity should normally be based on the needs of the users.

2.3. There is a considerable difference between needs and demands. While needs could be determined on the basis of biological and other measurable indices, the demand is essentially determined by the economic status and affluence of the people to be served. In developing countries where our resources are very limited we have to drastically cut the demands and base our standards or norms according to our needs. While the norms based on needs could be more or less universal, these are bound to be different if based on demand and would be higher for the affluent section and lower for the non-affluent section. Again, though the concept of the norms is closely linked with the needs and demands, yet it has also to be related with the resources, the technologies available and the social and other considerations.

2.3.1. Norms by themselves cannot ensure a particular quality of life. The concept of quality of life also is a relative term. Consider a settlement in any of the developing country, where the basic services are just not available. Will the provision of some of those facilities, though in a very rudimentary form, not improve the quality of environment ? If so, what norm should be followed for the provision of these services ? If we accept that bettering the qualities of existing environment be taken as a criteria then perhaps we could arrive at a more feasible approach to the question of deciding norms for housing as well as physical, social and economical services.

2.3.2. Hence, the standards for buildings and services should be decided as may be appropriate to the specific circumstances considering the needs and affordability of the users. The following broad criteria has to be kept in view while fixing them:

- : The standard and norms should be acceptable in the country as a whole, and amenable to modifications and improvements subsequently.
- : The standards should be such as would benefit the large section of low income families.
- : The standards can be based on needs or demands or the resources depending upon the specific situations.
- : Standards for urban and rural areas should be fixed separately according to their appropriateness for the concerned area.

2.4. Government Policies and Priorities - Housing has not been getting the priority that it deserves in the country's programme so far. It is heartening to note that in India this is now being realised that building construction in general, and housing in particular, needs greater attention.

2.4.1. With the higher priorities allotted to the building construction, the following steps will be required for its successful implementation:

: Increase in the production of building materials in the existing plants.

: Setting up of new plants and industries for production of additional building materials.

: Setting of new industries to produce new materials developed through R&D.

: Incentives to entrepreneurs for going into the production of such new materials and techniques.

: Enforcement of use of cheaper building materials and specifications without sacrificing the structural stability or functional utility of the buildings.

: Incentives to private sector and affluent sections of society to invest more and more funds in buildings.

2.5. Role of R&D in Evolving New Materials and Techniques - It is clear that the R&D has a positive role to play to achieve these goals. For the larger construction activities in the country, we have the over-powering constraints of financial and material resources. Hence, we have got to evolve appropriate technologies for building construction of all types, suitable to our present day economy. The problems for each sector will differ e.g. industrial buildings, residential buildings, schools, hospitals, marketing centres, recreational centres, offices etc. Similarly for rural areas different answers will have to be found out.

2.5.1. Generally when we think in terms of economy we restrict ourselves to materials and techniques for construction only. But it may be emphasised that proper physical planning also can reduce construction costs to a great extent. If we can increase the land use even by 10 percent, more land will be available without extra cost for construction of additional buildings. Similarly, the lengths of the roads could be reduced by proper planning which will again save large amounts of money not only in the construction of roads but in the services also. In the execution itself research could be helpful in providing management techniques to save in labour and time which ultimately result in cost saving.

2.6. <u>Role of Government Programmes of Large Scale Building Construction and Adoption of New Materials and Techniques</u> - At present large scale building construction is being carried out by various governmental and quasi-governmental agencies especially in the field of housing. It is, therefore, very essential that whatever new materials and techniques are developed in the research institute, these are utilized to the fullest extent by these construction agencies. The private sector will also follow suit. If one Government agency adopts such techniques, it will act as demonstration projects for other users.

Thus the Government agencies have to play triple role:

: That of a pioneer construction agency adopting new materials and techniques in their large construction programmes.

: That of an agency to give feed-back to the R&D institutes on the materials and techniques evolved by them; to identify problems in the field, and send them to research institutes for solution and advice.

: To act as demonstration agency for the use of these techniques by the public at large.

Chapter - III

3.0. BUILDING MATERIALS INDUSTRY IN INDIA

3.1. Although Building Materials industry plays a key role in the achievement of economic and social objectives, construction agencies in India continue to face shortages and uncertain supply of building materials. This is essentially due to absence of an organised sector in building materials industry except for cement and steel. Bricks and lime, which constitute two very important items of building materials, continue to be in an unorganised sector. Again, there are no proper organised arrangements for seasoning and treatment of timber.

3.2. A very large number of traditional building materials are available in India, and are being used extensively both in rural and urban areas. Out of these, the items of steel and cement being very important for building industries, they have each been allocated a separate sector for the purpose of this conference, and will be dealt with in their respective sectors. Similarly coal, though not used directly as construction material, is a very important item relating to building activity, as it is essential for burning bricks and clay tiles, both of which are a very common and important building materials, and will therefore be dealt with in the energy sector.

3.3. Apart from these 3 materials pertaining to the sector of heavy industries, the following are other important building materials which are generally used in building construction:

: Lime

: Flush door shutters and other factory made door and window shutters.

- Bricks manufactured by mechanised plants.
- Glazed earthen ware, sanitary and water supply fittings.
- Electric wires and other fittings.
- P.V.C. Pipes.
- A.C. Sheets and other A.C. products.
- R.C.C. Spun pipes.
- Stone-ware and cast iron pipes and other fittings.
- Doors and window fittings.
- Steel windows.
- Welded wire mesh.

Most of these materials are manufactured in medium scale industrial units of different capacities. However, due to the requirement of mechanical equipment, power supply and large investments in such production units, these cannot be established at the village level. They will need higher investment of capital and therefore few entrepreneurs can take up these industries for want of capital. Availability of raw materials and the existing demands for the materials will also determine the locations for their establishment.

3.4. Materials Based on Small Scale or Cottage Industries

The items that fall in this group are identified below:

- Bricks
- Lime
- Timber processing

- Steel fabrication
- Precast building components
- Stone ballast and grit
- Various types of tiles for building and decorative purposes.
- Roofing clay tiles.

Most of these materials are produced near every district or some important towns and sometimes even in important villages. They are mostly labour intensive and require comparatively less equipment and machinery and small investments. New entrepreneurs can therefore find a lot of scope in these industries.

3.5. Apart from the above traditional building materials a large number of building materials are available as agro or forest products which have been extensively utilised in rural constructions. They are:

- Timber (both primary and secondary species) and timber waste.
- Bamboo
- Reeds
- Thatch
- Palmyrah leaves

3.5.1. Some agro and industrial wastes are also available in good quantities which can be exploited for manufacturing new building materials. They are:

- Coir waste
- Lime sludge

- Fly ash
- Cinder
- Slag from steel plants
- Wood wool
- Sugar cane baggesse
- Rice husk
- Saw dust.

3.5.2. It will be seen that items identified in the above two categories have got much scope for utilisation in new building materials and techniques, as they have not yet been fully exploited. On the other hand, most of the items mentioned earlier are in extensive use since ages.

3.5.3. It will be seen that most of the above mentioned materials can be used both in the rural and urban sectors. However, certain materials are predominantly used in urban areas, while there is a specific group of materials which are used mainly for rural buildings and do not find a place in urban constructions. These materials are either available locally in the natural form or are manufactured locally from the available materials. These include:

- Hydraulic lime from kankar etc.
- Ballies
- Bamboo
- Clay tiles for roofing and flooring
- Thatch

: Palmyrah leaves

: Mud.

3.6. Improvements in the capacity and productivity of building material industry could result in large scale benefits through cost reduction and would even improve capital - output ratio of other industries, through interlinkages. Conditions of buoyancy in this industry inter-alia promotes growth in complementary industries like mineral industries, forestry (through backward linkage effect), furniture, textiles, domestic appliances etc. (through forward linkage effects).

3.7. Inspite of all the efforts made in the previous plan periods by the Government to improve the production of the building materials, the building industry continues to face problems of the same dimension and scale as in the past. The construction agencies continue to be faced with the variety of problems relating to erratic supply of building materials.

3.7.1. Rising Prices of Key Building Materials - A fair idea of this can be had from the following table:

Trends of Building Material Prices in India

Building materials	Annual compound rate of growth - 1970-75 (%)
Cement	2.9
Steel	3.2
Sand	1.6
Bricks	0.4
Timber	4.1

Source : Agenda for conference of State Ministers of Housing and Urban Development, Calcutta, December 1976.

3.7.2. Rising Construction Costs - The rise in the prices of building materials and wage rates has naturally resulted in the continuous increase in building costs, as will be clear from the following table:-

Item	Per annum compound rate of growth between 1970-75 (%)
1. Materials	3.30
2. Labour	5.40
3. Management	1.70
Total	3.25

Source : Ibid

3.7.3. Shortage of Building Materials - The Housing and Building Sector continues to face this shortage of most of the building materials. It was emphasised by the Working Group of Building Material, Manpower and Construction Technology for the 5th five year plan that to meet the entire plan needs for this sector, in the 5th five year plan, the output of bricks should be stepped up by as much as 13,500 million nos. Similarly, significant increase was sought in the output of other key building materials, such as cement (9.0 million tonnes), steel (2.9 million tonnes), and timber (2.0 million cu.metres). These targets were not only not achieved, but the shortages continued to remain of practically the same order as in the beginning of the plan.

3.7.4. Low Levels of Productivity - Because of preponderance of traditional operational skills in the industry, the productivity has kept at a low level. Also, since most building material industries are in the hands of a multitude of small enterprises, not much effort has been made to increase the productivity to the level so as to offset atleast the rising construction costs.

3.8. Factors Inhibiting the Growth of Building Material Industry - These factors have already been enumerated in para. 0.6.2. of this report. A comprehensive idea can be had by identifying the interplay of those factors in each key sector of the building material industry.

3.8.1. **Bricks** - Though much reliable data is not available on the output of bricks yet it has been estimated that 99% of the bricks are produced by the unorganised private sector. The problems faced by the industry are:

: Supply of coal, wood etc.

: Difficulty in getting land of a reasonable quality and at reasonable price.

: Inadequate R&D efforts and inadequate use of the available R&D results to:

- produce bricks from low quality soil;
- promote standardisation and quality in output; and
- effect savings in cost of production by improvement in thermal efficiency and using simple brick making machines.

: Absence of state and central level agency to promote coordinated policy on problems faced by the brick industry.

: Inadequate fiscal and monetary support.

: Want of effort on an appropriate scale to prove the techno-economic feasibility of some of the new products and processes.

3.8.2. Timber - Realistic estimates are again lacking about the availability of timber as it is mostly produced by unorganised sector. Yet, it is certain that existing demands of timber cannot be met from the present resources. As a result of this shortage, maximum incidence of price increase in the construction costs has been contributed by the rising cost of timber. This has also resulted in scarcity of seasoned or treated timber, which at times cannot be had at any cost.

Attempts made to use secondary species of timber have yet to take off. This is mainly because untreated or unseasoned secondary species of timber is totally unsuitable for construction work. Though about a hundred species of suitable secondary timber have been identified, adequate arrangements have still to be worked out, to supply the secondary species directly to major construction agencies, and for seasoning and treatment of timber.

Since timber accounts for about 11% of total cost of building materials and 45% of timber goes to construction industry alone, there is need for developing appropriate technology for conserving it. An integrated policy to conserve timber by rationalising its use,to utilise any waste timber for producing other useful building materials, to increase investment in affore-station programme, to ensure conservation of timber resources, etc., is most essential.

3.8.3. Cement and Steel - Similar shortages are being experienced in those two important building materials. The production as well as transportation and distribution suffer from serious problems which will not be considered in detail here, as they pertain to a separate sector for the purpose of this conference. Yet, it is obvious that it will be long before we will be free of the various inhibiting constraints on the production and distribution of these two important materials. Hence, there is a very great need of developing appropriate technology for using substitute materials in place of cement and steel, which should be conserved only for essential items where such substitution may not be possible or economically viable. There also, new techniques have to be evolved to minimise on the use of these two scarce building materials.

3.9. Some suggestions to overcome the above mentioned constraints are given below:

(i). A national policy is needed for the promotion of the locally available traditional building materials as well as for the adoption of new or alternative building materials developed through research.

(ii). A suitable legislation should be enforced to ban misuse of building materials, as has already been done in some of the developing countries.

(iii). Financial allocations for construction sector in general and housing in particular should be stabilised to reduce the vicissitudes of the fluctuation of the market.

(iv). The production of building materials should be linked with the construction programme of housing and development agencies. Also to ensure availability of materials in the desired quantities for fulfilling the plan targets, the 5 year plan of building material industry should be one step ahead of the construction and development plans.

(v). The brick and lime industries should be listed as priority items of small scale industry.

(vi). Tax incentives for encouraging building materials industry should be given. Some incentives by way of tax reduction and low transportation rates should be given to construction agencies also using locally produced and improved building materials.

(vii). To new entrepreneurs intending to take up production of building materials or components evolved by the research institutes, resulting in saving of materials and costs, incentives should be provided by way of financial assistance at low interest rates and with a moratorium period for refund, tax concessions, preference in supplies of raw materials, assurance of consumption of their output etc.

3.10. In the following chapters an attempt has been made to describe the appropriate building technologies and materials evolved through R&D by various Research Institutes in the country and their resultant benefits.

Chapter - IV

4.0. TRADITIONAL AND NEW BUILDING MATERIALS - IMPROVEMENTS THROUGH R&D AND TECHNO-ECONOMIC FEASIBILITIES OF PRODUCTION

4.1. Many developing countries have set a high priority for the establishment of new building materials industries for the ever growing requirements of their housing programme. Some of the most sophisticated technologies for the production of cement, bricks, A.C. sheets etc. are being imported from the developed nations by a few more fortunate developing countries. However, the majority is dependent on its meagre resources to make best use of the locally available building materials and improve upon the techniques and processes of the traditional building materials industries suited to certain national standards. It is in this field where the R&D organisations in India have worked out a number of new processes and schemes for a variety of building materials most suited both to urban and rural areas.

4.1.1. A number of R&D institutions are carrying out research work at present in India on building materials and techniques. Some of these institutes are listed below:

1. Central Building Research Institute, Roorkee.
2. Structural Engineering Research Centre, Madras/Roorkee.
3. Cement Research Institute of India, New Delhi.
4. National Environmental Engineering Research Institute, Nagpur.
5. Central Road Research Institute, New Delhi.
6. Regional Research Laboratory, Jorhat.

7. Indian Plywood Industries Research Institute, Bangalore.

8. Forest Research Institute, Dehradun.

These research institutes are carrying out work on various problems being faced by the construction agencies and the manufacturers in various regions of the country.

4.1.2. The National Buildings Organisation, New Delhi and its various rural housing wings are helping in the extension of research work done in the various institutes through its various publications, studies and reports and through the medium of news papers, radio, T.V. etc.

4.1.3. As a result of these activities, a large number of materials and techniques have been evolved by various laboratories. The main objective behind this has been to minimise the use of costly materials like cement and steel which consume a lot of capital, energy and transportation efforts for their production and distribution, and to increase the use of locally available indigenous materials so as to conserve capital, energy and transportation and to maximise employment generation. The results of these activities have been encouraging and some new materials and techniques evolved have already found large scale application in the field. Some of them have already been codified and Indian Standards are available for the same. A brief description of important new techniques and materials is given in the forthcoming paras:

4.2. <u>Traditional Low Cost Materials</u>

Soil, thatch, bamboo, timber, brick and stone are the main traditional low cost building materials. In most countries use of these materials has its own specialisations. However, there exists a lot of scope for improving the traditional techniques of soil stabilisation, making thatch roofs more durable, fire retardant, water-proofing of mud walls and making innovations in burnt clay brick and tile manufacture specially from highly shrinkable black soils and marine clays. Details of some of the work done by R&D organisations in this field in India are given below:

4.3. <u>Soil Stabilization</u>

Stabilization of soils, based on certain scientific evaluation of the physical and chemical characteristics needs more attention. Mud wall gets eroded due to rains and its protection by a cheap and efficient water proofing material has been the subject of research for many years. Whereas use of a low cost soil stabilizer to replace cement, lime or bitumen is very much desired, some training in the scientific methods of making stabilized soil blocks or even rammed earth wall is also essential.

4.3.1. <u>Water-proofing of Mud Walls</u>

The CBRI has brought forward a technique of water proofing the mud walls by spraying a mixture of bitumen and kerosene. This mixture can be easily prepared and sprayed on the mud walls by unskilled workers using a sprayer of the type used for spraying insectisides.

A drum containing 80/100 grade bitumen is heated till it melts. Kerosene oil is taken in another drum. The molten bitumen is added slowly to kerosene oil and vigorously stirred. The mixture is then sprayed within the time it remains fluid. A technical note (No. 14) published by the CBRI describes the technique in details. The cost is about Rs.1.80 per sq.m. of the wall area, and the life against erosion by rains is increased by 3 to 4 years.

4.3.2. Presses for Soil Stabilization

The CBRI has also developed one or two types of hand operated or mechanically operated brick presses with capacities of 100 bricks per hour and 250 bricks per hour respectively. The presses usually available on the market have low production capacity and do not give sufficient pressure required for making soil stabilized bricks or blocks. The presses which give about 100-200 Kg/cm^2 pressure are usually more efficient. Several countries have shown keen interest in laterite-lime or fly ash lime bricks because of the low requirements of energy and capital investment in their production. These presses could be produced for Rs.1,00,000 to 1,50,000 a piece.

4.4. Laterite-Lime Bricks

Attempts have also been successful in producing lime stabilized laterite bricks. Laterites are found in abundance in many areas and it is the only type of soil/rock, in several parts of India, African countries and South America. The laterite bricks are only sun dried and they give wet compressive strength of about 50-60 Kg/cm^2. Similarly, lime-fly ash soil stabilised bricks can also be manufactured around thermal power stations producing fly ash. A normal size 50 x 20 x 20 cm block of this type at 28 days moist curing gives compressive strength of about 20-25 Kg/cm^2. The CBRI (India) and SERC (india) both have studied the suitability of laterite as conventional aggregate for concrete.

4.5. Building Stone

There is a great history and tradition of the systematic quarrying and use of building stones. Stones of proven quality such as sand stones, basalt, marbles etc. are however being consumed indiscriminately. One of the problems is to utilise the small pieces of stone rejects. Two or three ways of utilisation have been developed by the CBRI. One of them is stone masonry blocks - using odd shapes and sizes of stones and a lean cement concrete mix. It is simpler, more economical and faster to build with such stone blocks and this idea has caught good attention in several states of India as an alternative to the random rubble stone masonry.

4.5.1. <u>Manufacture of Hydraulic Binder by Burning Limestone Rejects</u>

Siliceous lime stone rejects, on burning, give semi-hydraulic lime. The slate mine rejects and lime stone nodules found abundantly have also a good potential for making a hydraulic binder.

4.5.2. <u>Mechanisation of Quarrying</u>

There is a case for further improvements and mechanisation in quarrying, cutting and polishing of building stones and greater and wiser use of non-traditional stones. It will also effect savings of fuel and other raw materials used in the manufacture of cement and concrete.

4.6. <u>Bamboo</u>

Bamboo is abundantly grown in hot humid countries. There are many species of bamboo. In India, for example, the total production of all species is about 1.6 million tonnes. Only about 1/3 of this production is utilised to-day. There are several specialised techniques of using bamboo all over the World. There is a need to survey and collect all the relevant information on the availability and use of

Bamboo for rural housing. The Forest Research Institute, Dehradun (India) possesses invaluable information on the use of bamboo.

4.6.1. The CBRI has been engaged on the studies of use of bamboo as a reinforcement in cement concrete. The pretreatments of bamboo against moisture-swelling, decay and termite attack have also been attempted with encouraging results. However, the overall durability of such bamboo reinforced slabs has yet to be ascertained. Regional Research Laboratory (Jorhat) has also worked on the use of bamboo along with cement mortar for roofing purpose.

4.7. Secondary Species of Timber

In most developing countries timber is costly and first class timber is mostly used for luxury houses. It would be a wise decision to use as much secondary species as possible and avoid wasteful and indiscriminate use of costly first class timbers.

4.7.1. Seasoning cost involved in the use of secondary species of timber are common problems. The CBRI has developed a solar seasoning kiln in which timber like mango (magnifera indica) and jaman (syzygium cumini) have been successfully seasoned thus eliminating use of any fuel for steam seasoning. This kiln is made from a timber frame and glass sheet coverings. The seasoning is about 50% quicker than the normal air seasoning. The Forest Research Institute, Dehradun has also developed a solar seasoning kiln. These should find a wide application in these developing countries where sun is plentiful.

4.7.2. Cutting and sawing of timber produce about 40% wastes of the weight of the original timber. A substantial amount of waste as branches and leaves (pine needles) etc. are just allowed to decay in the forests. There is a great scope for systematic collection and use of such timber wastes, some of which could also be used to produce wood based panel products. The Indian Plywood Industries Research Institute, Bangalore (India) has developed an economical roofing system using waste veneers.

4.7.3. Wood Cement Products

Wood cement based products can be produced in densities ranging from 300 to 1300 Kg/m^3. Such boards are much cheaper than the wood particle boards bonded with U.F. or P.F. resins which are imported in many countries. Wood-wool boards is one such type of cement bonded panel product. The CBRI has developed a low capital scheme for making such boards and has also identified cheaper species of timber from which wood wool could be made at a production cost of Rs.8 to 10 per sq.m.

4.8. Coir Fibre Cement Board/Sheets

Development work has been completed in the CBRI in the utilisation of coir wastes, rice husk, ground nut hulls etc. for making boards. Such wastes are now becoming more and more available with the development of agro-industrial complexes. Table 1 gives properties of coir fibre cement bonded building boards. These boards could be used as infil panels for timber or RCC or metal frame structures, as permanent shuttering for concrete, erection of free standing and sound proof partitions for false ceilings as well as roofs.

4.8.1. The CBRI has also developed a roofing sheet (Table 2) made of coir fibre wastes and cement. The sheets can be used for semi-permanent roofs in the same way as A.C. sheet but costs only half.

These sheets have been given a cheap water-weather proof coating, which has about 10 years of life. These sheets are more impact resistant and thermal insulating than A.C. Sheets. This industry could be set with an investment of about Rs.0.2 million to produce about 100 roofing sheets per day.

Table 1

PHYSICAL PROPERTIES OF COIR BUILDING PANEL

(1).	Size (cm).	300 x 100 x 5
(2).	Bulk density (Kg/m^3).	500 - 650
(3).	Texture	Smooth
(4).	Moisture absorption (%) (24 hrs.)	10
(5).	Bending strength (Kg/cm^2).	9.5 for 5.0 cm thickness
(6).	Thermal insulation (KCal/m^2/h/C°)	0.082 to 0.090
(7).	Sound absorption (NRC).	0.32

Table 2

PHYSICAL PROPERTIES OF CORRUGATED ROOFING SHEETS

		Coir-cement	A.C.
(1).	Pitch of corrugation (mm).	145	146
(2).	Depth of corrugation (mm).	48	48
(3).	Length (m).	1.5 to 2.0	1.5 to 3.0
(4).	Broadth (m).	1.0	1.05
(5).	Thickness (mm).	7	6
(6).	Weight (Kg/m^2).	11.0	13.0
(7).	Water absorption (24 hr) (%).	1.0 (with water-proofing)	25 (max.)

(8).	Breaking load	Coir-cement gives equal strength at 0.6 m spacing as compared to 1.0 m spacing of A.C. sheet.	
(9).	Thermal Insulation, (K Cal/m²/h/C°)	0.09	0.24

4.9. Corrugated Asphaltic Roofing Sheets

Asphaltic roofing sheets are now being produced in several countries but their life in tropics is very short. The CBRI and RRL (Jorhat, India) have developed a more durable type of asphaltic paper board roofing sheet with an expected life of about 7-10 years. This sheet would cost about 1/3 of the A.C. sheet. The commercial production of this sheet has been licensed to a party in India and in Phillipine.

4.10. Magnesium Oxychloride Saw-Dust Door Frames

Sorel cement or magnesium oxychloride cement is generally used for railway coach flooring. It is produced from magnesite, magnesium chloride and fillers. A technique to make oxychloride cement bonded saw dust door and window frames has been developed by the CBRI and a large number of such frames have been used in the houses constructed in Ahmedabad, a large industrial town of India. These frames are being sold at about 40% less cost than the first class timber frames. The frame can take good impact, can be sawn, nailed, can be repaired by patching and is free from the attack of termite. However, these frames require proper painting regularly and should not be used in fully exposed conditions.

4.11. Fire Proofing of Thatch

The CBRI has developed two types of materials which on impregnation or spraying make a thatch fire-proof. There has been a successful demonstration of these materials and a technical note published by the CBRI describes the method in details. The usually available di-ammonium phosphate forms the basis for formulations of these fire-proofing materials. Plastering with bitumen stabilised mud both inside and outside of the thatch roof also renders it fire retardant.

4.12. Burnt Clay Bricks and Tiles

The use of burnt clay bricks and tiles is an age old tradition and is preferred for low cost housing in many rural and urban areas. But bricks and tiles are getting expensive due to high cost of the fuels used. Attempts therefore have been made to produce good bricks and tiles in more efficient kilns with lower fuel consumptions. The clay flooring tiles are being used for water proofing of terraces and cost Rs.400-500 per 1000 tiles.

4.12.1. The non-availability of good soils for making bricks is also a problem. The CBRI has developed several techniques to improve the quality of bricks from traditionally unsuitable soils such as black and red soils and tiles from alluvial soils. These techniques have been used on commercial basis in many parts of India. The 'Grog' (precalcined clay) as an admixture in black soil has been especially adopted widely. The Institute has also developed a high draught brick kiln costing about Rs.0.2 millions which consumes 15-20% less coal than the usual bull's kilns. Recent trials in the use of admixtures such as fly ash with soils, and firing the bricks with agricultural wastes like rice husk can show a new approach for small scale manufacture of burnt clay bricks and tiles with considerable saving in traditional fuels. The work of CBRI on making clay-fly ash bricks can to a great extent solve the problem of disposal of waste fly ash. Fly ash could also be very usefully utilised for making fly ash-sand-lime type bricks.

India produces and exports very good quality Mangalore pattern roofing and flooring tiles. Small or large scale manufacture of those tiles are carried out as most of the plant and machinery are indigenously available.

4.12.2. Semi-Mechanisation in Brick Making

Highly mechanised brick plants have not proved very successful in many countries because of lack of well trained people to operate them. Such plants are also very costly. Attempt should therefore be made to develop simple machines, which may be even portable, for making pressed bricks. A number of so called difficult or unsuitable soils when pressed and fired make good quality bricks. The CBRI has developed a semi-mechanised brick making plant requiring a capital investment of about Rs. one million as against Rs.5 to 6 millions for a fully mechanised plant. The machine made bricks give high strength and therefore can be readily used in load bearing single brick thickness walls for 3 to 4 storey buildings in urban areas. The CBRI brick making machine has so far been adopted by about 15 brick manufacturers in India.

4.12.3. Sand-Lime Bricks

Sand-lime bricks could be an ideal new material in many parts of the west and S.E. Asian countries where sand and lime are cheap. Lime-silica cellular concrete is another material under this category. Since such plants are fully automatic and can run round the year, they are therefore suitable for urban areas demanding prefabricated construction. Such plants are also capital intensive costing around Rs.10 million. These materials are now being increasingly used. However, careful planning and decision is required about setting up industries to produce these materials. Complete technology is available with W. Germany, England, Poland and the USSR.

4.13. Lime Based Masonry Cements and Plasters

With the advent of cement lime as a building material has been practically forgotten. Its use is discouraged by many engineers on the grounds that it is not available readily and its slaking etc. requires more time and labour. There is now a common practice in advanced countries to market ready mixed dry lime mortars which could be used only with the addition of water. The CBRI has proposed several lime based ready to use materials some of which are : (i) Masonry cement made from a mixture of waste lime sludge from sugar or paper mills and cement. It gives comparable strength in 1:5 masonry cement-sand mix as against 1:6 cement-sand mortar with a saving of 40 to 48%; (ii) Rapid setting lime-pozzolana mortar and plasters - based on lime kiln rejects and locally available ashes etc., (iii) Lime sludge + Rice husk cementitious material and rice husk pozzolana - a very suitable and cheap binder for rice producing areas. Almost any pozzolanic material such as fly ash, cinder, burnt clay, brick surkhi, kiln ashes, fuel ashes, rice husk ash etc. could be used to prepare the lime based dry mortars which should find good application for 1 to 2 storey buildings.

Industries are now being set up in many parts of India to produce standard quality lime-pozzolana mixtures.

4.14. Cementitious Binder from Rice Husk

The CBRI has developed a cheap binder by burning waste rice husk and the lime sludge thrown out of sugar and paper industries. No extra fuel other than rice husk is required. The technique is also quite simple. The cakes of the mixture of sludge and husk are dried in the sun. After burning and grinding they give a fast setting grey colour cementitious material. There is substantial economy if this binder is used in place of cement or lime. This material is also suitable for brick masonry mortar and plaster and foundation concrete (Table 3 and 4). There should be no difficulty in popularising the manufacture and use of this material for low cost buildings even in remote rural areas. This binder can be produced on small scale (10 t/d) with an investment of Rs.0.2 million. Similar studies have been carried out by RRL, Jorhat who have also successfully made rice husk ash cement.

Table 3

PROPERTIES OF RICE-HUSK CLAY POZZOLANA

Coarsely ground material:

Surface area 2600 cm^2/g (Blaines).

Compressive strength of mortar : 10 kg/cm^2

(IL, IP, IS).

Finely ground material :

Surface area 8000 cm^2/g (Blaines)

Compressive strength of mortar : 70 kg/cm^2

(IL, IP, IS)

Table 4

PROPERTIES OF HYDRAULIC BINDER FROM RICE HUSK LIME-SLUDGE

Finely ground material:

Surface area 8000 cm^2/g (Blaines)

Compressive strength of mortar : 50 kg/cm^2

(1:3)

Setting time:

Initial	60-70 minutes
Final	480-600 minutes

4.15. Lime Kilns and Hydrators

The CBRI has developed several designs of lime kilns ranging from 3 to 15 t/d capacity production. Such kilns constructed in brick or stone masonry with fire brick lining cost Rs.55,000/- for 5 tonnes/day and Rs.75,000/- for 10 tonnes/day kiln.

The CBRI design - lime hydrator - a 3 tier semi-mechanised machine produces 10 tonnes lime/8 hours and it costs Rs.50,000/- including a small bucket elevator.

4.16. Slag Cements and Portland Pozzolana Cements

The constraints on the cost and availability of portland cement must be taken into account in the overall planning of low cost housing. Attempts are being made by many countries to set up their own cement industry. Simultaneously more and more blended cements such as portland pozzolana cement, portland fly ash cement and portland blast furnace slag cement should also be produced. All these cements utilise waste materials as substitution of portland cement from 20 to 50% and as such there is an increasing trend in the utilisation of the solid wastes effecting overall saving. CBRI has developed a special method of proportioning fly ash-cement-concrete for 20% replacement of cement.

4.16.1. Mines and mineral processing industries such as beneficiation of gold, copper, zinc, iron and aluminium ores throw out enormous quantities of very fine siliceous and dolomitic wastes. These wastes can be utilised in making masonry mortars, fillers for concrete blocks, flooring tiles etc. The CBRI has given several recommendations on the utilization of such wastes.

4.16.2. In phosphoric acid, hydrofluoric acid and ammonium phosphate fertiliser industries, gypsum is thrown up as a waste material. The CBRI has shown that this waste can be utilised successfully for a cheap plastering material as well as to produce super-sulphated cement which usually has a combination of 70% granulated blast furnace slag, 15-25% waste gypsum and 5-10% portland cement. Alumina, red mud waste from aluminium industries, could also find use in blended cements to a certain extent. Further work on the utilisation of phospho-gypsum relates to the development of beneficiation process to up-grade this waste gypsum and also a kettle calciner for making gypsum plaster.

4.17. Aggregates - Availability of stone aggregates in certain parts of the developing nations is a problem. The new sources for aggregates must be tapped, the chief among which are (a) air cooled and foamed blast furnace slag - an excellent material for concrete, (b) colliery wastes as light weight aggregate for making concrete blocks, (c) slag wastes from foundries and mini steel plants,

(d) manufactured light-weight aggregates - by bloating or sintering of water works silt or fly ash, (e) stone mining rejects and (f) laterite stone rejects, slate and shale wastes. The CBRI has also developed a simple fluidized kiln for making exfoliated vermiculite for use in heat insulating plaster.

4.17.1. Utilisation of the above mentioned materials would greatly solve the problems of aggregates in places situated far away from stone quarries. In many cases the evaluation of these types of aggregates has already been completed by the CBRI and pilot plants have been set-up for routine evaluation and reports on the suitability of various raw materials. However, in most countries light weight concrete is economical only in multi-storey constructions and for this reason the use of light weight aggregates is so far very limited in India.

4.18. Techno-Economic Feasibility Reports

A number of new materials mentioned above have been extended to commercial manufacture. Project proposals have been worked out by the CBRI for these techniques. The proposals contain the requirements of equipment, machinery and other inputs and operating costs etc. to help the entrepreneur in working out the economics of their production. Some of the processes for which project proposals have been prepared are given below:

(1). Manufacturing of expansion joint filler from CNSL.

(2). Production of sintered aggregate from fly ash.

(3). Building lime from sugar press mud.

(4). Production of Particle Board from coconut husk.

(5). Gypsum plaster board.

(6). Production of bricks by a semi-mechanised process.

(7). Fire Resistant Building Boards from coconut pith.

(8). Good bricks from black cotton soil.

(9). Good bricks from red murram soils.

(10). New formulation of cement paint.

(11). Water and weather proofing resin composition.

(12). Bloated clay aggregate.

(13). Engineering bricks/paving bricks/acid resistant bricks.

(14). Cement coconut pith concrete for thermal insulation.

(15). General purpose and heavy duty flooring tiles from magnesium oxychloride cement.

(16). Preparation of partially calcined dolomite magnesium oxychloride cement compositions.

(17). Fire Retardant impregnant for wood.

(18). Corrugated roofing sheet from coir fibre and cement.

(19). Corrugated Asphaltic Roofing Sheet.

(20). Manufacture of activated Lime Pozzolana Mixture.

Chapter - V

5.0. APPROPRIATE CONSTRUCTION AND PLANNING TECHNIQUES

5.1. The huge requirement of buildings in all the developing countries calls for all out efforts in mobilising the required resources and in developing appropriate building techniques and systems taking into account the technological development, the skills and the materials available in the countries. As capital available in India is limited and man-power is plentiful, it would be more appropriate to go in for manual methods of construction. However, there is a good deal of scope for bringing about improvement in the conventional methods of construction and making them more productive without excessive use of capital and energy. The main aim of research in construction techniques has, therefore, been to develop such improvements in construction techniques which will minimise the use of expensive materials like cement and steel and will improve the quality of work and accelerate the pace of construction. Keeping these aspects in view, some of the techniques developed in India are described below:

5.2. Foundations

5.2.1. Under-reamed Piles

These are suitable for sites with heavy filling, high water table or having black cotton soil (expansive soil) or loose sandy soil. The percentage saving in foundation cost compared with traditional foundations range from 20 to 50 percent. These are useful for various types of structures such as multistoreyed buildings, storage tanks, transmission line towers. These have been successfully adopted on a large scale in India and have also been used in other countries like Dubai etc. These have also been codified and I.S.2911 (Part III-1973) deals with under-reamed pile foundations.

5.2.2. Bored Compaction Piles

These are in-situ concrete piles in which the compaction of the concrete as well as of the surrounding soil is effected simultaneously by driving in the reinforcement cage through the freshly laid concrete. The compaction increases the load carrying capacity of the piles by 50 to 100 percent over normal piles. These are particularly suitable in loose to medium sandy and silty strata with or without water table close to the ground surface. These have been adopted on a large number of projects during the last five years and have resulted in an economy of 30 to 50 percent compared with conventional types of foundations.

5.2.3. Hyperbolic Paraboloid Shell Foundations

This is formed by a straight line moving in a direction which results in easily adoptable structural form work for providing footings of columns. This is suitable for four and above storeyed framed buildings foundations in case of soils having poor bearing capacity. It provides an economy of 10-15 percent against conventional RCC footings.

5.3. Walling

5.3.1. Single Brick Thick Load Bearing Walls

The wall is designed like any other structural element and IS 1905-1969 code of practice for structural safety of buildings - Masonry walls, provides adequate data for the design of wall thickness taking into account the strength of brick and mortars. With bricks of 105 K/cm^2 a large number of four storeyed residential buildings have been completed with single brick thick wall in all the four floors. This has resulted in reducing the cost of walling by 20-30 percent.

5.3.2. Half Brick Load Bearing Walls

For buildings of small heights and light loads, half brick thick wall as load bearing has been adopted recently in a number of low cost housing projects. These walls are, however, not very suitable for external locations from the point of view of thermal insulation and resistance to rain penetration. A half brick thick staggered wall is structurally adequate for normal residential buildings of even upto three storys.

5.3.3. Precast Stone Masonry Block Walling

For areas where stones are available, a simple technique of prefabrication making use of stone spalls upto 15 cm size and lean concrete mix of 1:5:8 cement:sand; stone aggregate 10 mm and down has been evolved to make blocks of 30 xm x 20 cm x 15 cm nominal size. The average compressive strength of such blocks is 70 Kg/cm^2 and any other desired strength can be obtained by suitably modified mix proportion. Load bearing walls of 20 cm thickness have been successfully adopted for three storeyed residential buildings and 15 cm thickness for double storey small residential buildings. This technique saves in consumption of materials, increases productivity, require less skilled labour and provides an economy of over 20 percent against conventional random rubble masonry. This has been successfully adopted in over 1200 houses in various parts of the country.

5.3.4. No Fines Concrete Blocks

In several areas sand is not available and has to be transported from long distances. For such areas no-fines concrete blocks of 1:10 cement:aggregate in 30 x 20 x 15 cm nominal size have been produced. These blocks have a compressive strength of 35-40 kg/cm^2 and can be used for load bearing walls in single storeyed buildings and as filler blocks in framed construction.

5.3.5. Hollow Concrete Blocks

These have been used in load bearing walls for buildings upto two storeys and machines to produce such blocks are being made in the country. These have also been used as filler blocks in framed buildings.

5.3.6. Cellular Concrete Blocks

Lime flyash blocks and cellular concrete blocks are being produced at a few places and have been used for load bearing and non-load bearing walls.

5.3.7. Large Panel Prefabrication

Industrialised methods of construction adopting room size wall and floor/roof panels have been widely adopted in western countries as these save in labour hours and construction time. The Central Building Research Institute, Roorkee has carried out research studies and for the production of large panels battery casting technique with concrete moulds has been perfected. Studies have also been made for jointing techniques and typical details for joints between wall to wall, floor to floor and wall to floor have been worked out. The S.E.R.C. has also done good work in development of large panel prefabrication. Multistoreyed construction of houses and other buildings using large panels has been adopted at Delhi, Bombay and Madras. However, in all these, it has been found that the initial capital investment required for production, transportation and erection is quite large, employment potential is much less and the consumption of scare materials like cement and steel is comparatively higher. Further the walls with RC panels are thermally inferior as against one brick thick wall. For tropical climate, the walls have to be provided with sandwitch panels which make the cost exhorbitantly high. The walls are also not very suitable for fixing or nailing utility fixtures from time to time. As such this has not found much use in this country.

5.4. Doors and Windows

5.4.1. Secondary Species of Timber

A number of secondary species of timber have been found to be satisfying the needs of building construction and these should be seasoned and treated before using them.

5.4.2. Magnesium Oxychloride Cement and Saw Dust Frames

A process of making door and window frames using magnesium oxide power, magnesium chloride, marble, or dolomite powder and saw dust as filler has been developed. These frames compare well in cost with timber frames and the shutters can be fixed with hinges and wood screws in the same way as on any timber frame. These can be easily erected at site and painted.

5.4.3. Steel/Angle Iron Frames

These can be made of angle iron or M.S. flats. A size of 40 x 30 x 5 mm is suitable for shutters of 30 mm thickness.

5.4.4. R.C.C. Frames

These are of 6.5 cm x 8.5 cm size and have 3 bars of 6 mm dia with 3 mm wire ties at 15 cm on centres. For fixing shutters, helical spiral of binding wire or aluminium tube threaded inside are placed during concreting. For low cost houses these may be used as they are slightly cheaper but these have the limitation of edges being chipped off.

5.5. Lintels

5.5.1. Flat Brick Arches

These are suitable for small spans and conserve steel and cement.

5.5.2. Stone Slabs

In some parts of the country like Rajasthan, Stone slabs of sufficient thickness and length are available. These are used as lintels.

5.5.3. Thin Precast R.C. Lintels

There is a composite action between R.C. lintel and the brick masonry on top and as such lintels can be designed on the principle of plinth beam. It has been tested and seen that for openings upto 1.8 m, 7.5 cm thick precast lintel with 3 bars of 10 mm dia and 45 cm brick masonry are sufficient. For spans between 1.2 to 1.8 m lintel with only 2 bars of 10 mm dia placed centrally and having brick masonry of 30 cm on top of lintel are adequate. The precast lintel should be propped till the brick masonry laid above attains strength. The bearing of the lintel should not be less than 15 cm.

5.6. Roofing

5.6.1. Arch Roofing

(a). Before the development of reinforced concrete slab, the jack arch roofing was adopted with R.S. joists on a large scale. The RS joists can be replaced with precast R.C. joists and it saves in cement and steel.

(b). The CBRI has also worked on precasting the brick arch panels of 120 cm x 50 cm x 7.5 cm which can be placed between precast R.C. joists. This eliminates the shuttering and saves on cost.

(c). Work has also been done to lay brick arches with a camber of 5 - 7.5 cm using gypsum mortar in between precast R.C. joists. In this also no shuttering is required as gypsum mortar sets quickly and holds the brick in position. This technique is to be adopted in areas where the rainfall is scanty as moisture should not come in contact with gypsum mortar.

5.6.2. Reinforced Brick and/or Reinforced Brick Concrete Slabs Cast-in-situ

For reinforced brick slabs, bricks are arranged with gaps between them on the shuttering and reinforcement is placed in the gaps in both directions. Cement mortar 1:3 is then filled in the joints. The bricks take the compressive stresses and depending on the span the slab thickness varies from 11.5 cm to 15 cm. The bricks should not be less than 105 kg/cm^2 and should be free from salts with low water absorption. This technique is adopted in Uttar Pradesh where good quality bricks are available. The experience indicates that RB slabs last only for about 25 years as the reinforcement starts getting corroded. This technique is not suitable for coastal areas.

The improvement over the RB slab is to have RBC slabs. In this case the bricks are laid on the shuttering with gaps of 30 mm or more and after placing reinforcement, M-150 concrete is filled in the joints and also a deck concrete of 30 mm or more is laid all over the bricks with distribution reinforcement in both directions. In this case bricks act as filler blocks and compressive stresses are taken by concrete. In this case also bricks should not contain salts and be of less water absorption to avoid corrosion of reinforcement. This has been adopted in large scale housing by the U.P. P.W.D. and U.P. Housing Board as it saves in cement and also in cost.

5.6.2.1. Prefab Reinforced Brick Concrete Panels for Roofing/Flooring

In this, bricks are arranged flat in a timber mould of internal dimensions (56 cm x 104 cm) and this size of the mould has been so made that 16 bricks are laid. Two 6 mm dia M.S. bars are placed as reinforcement in the outer joints and all the joints (2.5 cm wide) are filled with M-150 concrete. These panels, after curing, are lifted and placed on partially precast R.C. joists which are spaced at 1.2 m centres and cement sand mortar is applied on sides of the panels while placing them in position. Temperature reinforcement of 3 mm dia wire is placed both ways over the panels and 3 cm thick M-150 concrete is laid in-situ on the entire area which forms the compression flange and the bricks act only as filler material. By this method saving of 20% in cement, 30% in bricks, 40% in steel and 33% in the overall cost is achieved against the in-situ 11.5 cm thick reinforced cement concrete slab. Apart from this, it eliminates the shuttering for the slab and only props for the partially precast joists are needed.

5.6.3. Funiculor Shell Roofing

These are doubly curved shells of 1.2 x 1.2 m or so and have edge beam alround which contains nominal reinforcement of 6 mm dia. There is no reinforcement in the body of the shell and the shell concrete thickness is 30 mm. These shells are placed on partially precast R.C. joists or after placing the shells on shuttering, the joists are cast in-situ also. Along the joist, concrete is filled upto the crown of the shell and across the joists, the haunches are filled with lime concrete or lean cement concrete. This technique saves in cement and steel and has been adopted in a large number of housing and office buildings. The sizes of shells can be even full room size but in such cases shuttering is required and the shell is cast in situ.

5.6.4. Madras Terrace Roofing

This technique was being adopted in southern states with specially made terrace bricks placed on their edges in a diagonal pattern using lime mortar or lime cement mortar over the wooden joists spaced at 30 to 45 cm apart. This technique saves in steel and cement but it is now not being adopted probably because of its high cost. By using secondary species of timber or RCC battons, this technique could be revived.

5.6.5. Structural Clay Units for Flooring/Roofing

Two types of structural clay units have been developed. In one case the flooring/roofing panels are built like brick walls with reinforcement placed in one of the grooves. These panels are lifted and placed horizontally to form the roof.

The other type is a joist and filler block type construction in which, using the same shape and size of the units both for joists and fillers, the roof is formed.

Both these save 45 to 65 percent in cement and 20 to 25 percent in steel. The structural clay units are produced by extrusion process and a machine is a must.

5.6.6. Clay Tiles and RCC Battons Roof

This technique has been used in Punjab. The brick tiles are laid over RCC joists and this does not need form work. This saves in cement and steel.

5.6.7. Precast Cellular Concrete Units

These are un-reinforced hollow precast concrete units of nominal size 120 cm x 60 cm x 7.5 cm. Those are used alongwith partially or fully precast RC joists. The scheme results in saving of about 20 percent in cement, 50 percent in steel and 30 percent in overall cost against RC slab.

5.6.8. RC Channel Units

These are reinforced concrete trough type units 30 cm wide by 13 cm deep and are suitable for spans 2.5 to 4.25 metres. These do not require any propping. These have been adopted on a very large number of housing projects by the Military Engineering Service and for the primary schools and health buildings in rural areas. This saves 40 percent in cement, 4 percent in steel and 20 percent in cost.

5.6.9. Cored Units

These are reinforced concrete, hollow box type units of 30 cm width by 13 cm thick and are suitable for spans 3 m to 4.5 m. The saving in cement is 25 percent. This has been adopted in over 500 houses and because of pre-fabrication it saves the time of construction and provides flush ceiling.

5.6.10. Precast RC Planks

This comprises of RC beams and RC planks partly 5 cm and partly 2.5 cm thick. The beams with in-situ concrete forms the slab and the flooring is done directly over the planks. The scheme saves 45 percent in cement 20 percent in steel and 25 percent in overall cost against R.C. slab. The scheme has been adopted in over 500 housing projects. The scheme also provides monolythicity in the slab and the jointing details are such that the chances of leakages are considerably reduced.

5.6.11. Precast Batton and Hollow Block Construction

In this scheme partially precast R.C. battons are placed in position and precast hollow blocks of concrete are laid in between these battons. This scheme has been adopted in a large number of housing projects by Hindustan Housing Factory Limited, New Delhi. This provides a saving of 10 to 15 percent in cement and 5 percent in steel as compared to conventional in-situ R.C. slab.

5.6.12. Precast R.C.'L' Pan Units for Sloping Roof

In this scheme cladding and purlins have been both combined into one unit thereby saving in materials, cost and time.

5.6.13. Precast Waffle Units

The waffle units are open box type units of square or rectangular shape between 60 cm to 120 cm. The depth will vary according to the span. After placing the waffle units on partial shuttering, reinforcement is provided in the joints between adjacent units at right angles. There is no deck concrete provided on the top. This scheme results in a saving of 15 percent in cement, 10 percent in steel and 10 percent in cost compared to traditional Tee beam and slab construction.

5.7. Finishing

5.7.1. Lime Plaster

Lime mortar was extensively used before the advent of cement and buildings built with lime mortar are still standing. Its better workability, higher water retentivity, higher bond strength, and capacity of autogenous healing is a positive advantage over cement mortar. Due to good quality of lime not being produced, there has been resistance in use of lime mortar. Hyderated lime is now being produced and is being supplied in bags in the same way as cement and it is high time that this is used.

5.7.2. Building Lime Products

The CBRI has developed activated line pozzolanic mixture which is having all the properties of adequate strength, better workability and high water retention. This material is also being supplied in bags and it is suggested that this be used for plaster for masonry work and also for base concrete work.

5.7.3. Composite Mortars

Against the use of plain cement sand mortars which develop cracks due to shrinkage and thereby cause ingress of moisture, it is suggested that composite mortar of cement:lime:sand in proportions of 1:1:8, 1:2:9 or even 1:3:12 should be used as per design requirements.

5.8. Building Services

5.8.1. Single Stack System of Plumbing

The Central Building Research Institute, Roorkee carried out experiments on a mock up using a single stack for all discharge with unventilated traps and observed that there was no break of seals. This system has been incorporated in IS:5329-1969 and several organisations are adopting it. It saves 54% in over all cost and 60% in labour as compared to conventional two pipe system.

The Institute has also carried out studies on one pipe modified system in which the appliances at alternate floors are connected with antisyphonage pipe and it has been found that the load carrying capacity of the 100 mm dia stack is increased and this system works out to be economical for buildings of 10 - 12 storeys.

Another development made at the Institute to increase the limiting capacity of normal single stack is of special fittings 'Aerator' at each floor level and 'Deaerator' at the bottom of the stack. With these fittings 100 m dia stack can be used for buildings upto 15 storeys.

5.8.2. Dual Flushing Tank

The flushing tanks in use discharge their full capacity even though the W.C. has been used for minor purposes. To conserve water, a dual flushing cistern has been designed and developed by the Central Building Research Institute, Roorkee. This involves very low additional cost but can lead to considerable economy in water consumption.

5.8.3. Small Capacity Flushing Cisterns

By rationalising the water seal area in the European type W.C. pans and the spacing and direction of holes in the rims of Indian pans, it has been seen that efficient flushing is achieved only with 6.5 litres against the 10 litres used at present.

5.8.4. Automatic Flushing Cistern

For urinals in office buildings, public places etc. the automatic flushing cisterns are used. The fittings for achieving this are made up of brass and are quite costly. The CBRI has developed a very simple fitting of polythene pipe which is very cheap and efficient in working.

5.9. Techniques Suitable for Rural Areas

Although the techniques mentioned above are suitable for adoption in the rural areas also, but because of the shortage of materials and the requirements of housing in rural areas being gignatic, it is suggested that more and more use of locally available materials with improvements in the local construction practices be adopted for upgrading the durability and liveability of village houses as well as for providing the scope for self-help methods of construction to the maximum.

5.9.1. Foundation and Plinth

5.9.1.1. The foundation can be laid in burnt bricks or in random rubble stone masonry or laterite blocks in lime mortar. In areas where water table is very low the masonry can be laid in mud mortar.

5.9.1.2. The entire foundation can also be laid with boulders, gravels, kankar with moorum, properly compacted to form the structure base over which to lay the superstructure.

5.9.1.3. Stabilised soil blocks with cement, lime or bitumen. These are also suitable for foundation. In this case the mixing of stabiliser has to be thoroughly done and in case water table is high bitumen painting is to be done on the sides of masonry upto the ground level.

5.9.1.4. In areas where rain fall is scanty, the superstructure can be started on rammed earth only for single storeyed light buildings.

5.9.2. Damp Proof Course

5.9.2.1. At the plinth level, a course of burnt bricks soaked in soap solution shall be laid in lime or cement mortar.

Alternatively, lay a course of burnt bricks dipped in coal tar with coal tar sand mortar. In place of coal tar burnt engine oil may also be used.

5.9.3. Walling

5.9.3.1. Locally available burnt bricks, stones, or laterite blocks laid in mud mortar or lime mortar. In case mud mortar is used, the wall should be pointed with lime mortar or cement mortar, or composite mortar.

5.9.3.2. Mud walls could be of locally available well kneaded clay or sun dried clay bricks laid in mud mortar. These should be internally plastered with mud mortar and externally with water proof mud plaster made of Bitumen cut back or by spraying bitumen over the wall, or by applying mud plaster mixed with burnt engine oil.

5.9.3.3. The main structural members could be of timber or ballies or bamboos and the cladding of split bamboo jaffri, reed panels or palmyrah leaves. These should be plastered with mud mortar internally and the external surface can be with non-erodable mud plaster.

5.9.4. <u>Roof</u>

5.9.4.1. Flat roofs made up of wooden joists, or ballies or bamboos having country wood planks, reeds of bamboo mat covered with a layer of well compacted soil and mud plastered. The top of this may be rendered with bitumen cut back mixed in mud plaster.

5.9.4.2. Stone slabs of 60 cm wide by 10 to 12.5 cm thick and upto 3 m span resting on walls may also be used.

5.9.4.3. Local wood, bally or bamboo trusses or rafters covered with thatch, reeds, palmyrah leaves, country tiles, slates etc., depending on the availability in the region are also in use.

5.9.4.4. G.I. sheets or A.C. sheet roofing with wooden ballies as rafters and bamboo as purlins are sometimes used.

5.9.4.5. <u>Corrugated Wood Wool/Coir Boards</u>

The Central Building Research Institute has developed 2 types of roofing sheets, one with wood wool and the other with coconut or jute coir waste. In both, cement is used as a binder. These sheets are made in sizes of 1 x 2 m and cost about half of the A.C. sheet.

5.9.4.6. Asphaltic Roofing Sheets

These sheets are made from pressed paper boards impregnated with asphalt. The life of the sheets is 5 to 7 years and these are suitable for temporary buildings. These sheets are not to be used in areas where temperature in summer is likely to be above 45°C.

5.9.4.7. Bamboocrete

The Regional Research Laboratory, Jorhat, has made use of locally available bamboo in walling as well as in roofing. The bamboo-crete roof was constructed of the shape of a cylindrical shell by arranging pretreated bamboo splits in both direction in the form of an arch and then applying two coats of cement sand plaster. Apart from low cost, this technique is labour intensive and can be adopted on self help basis also.

The Central Building Research Institute, Roorkee and the Forest Research Institute, Dehradun have also made use of treated bamboo as reinforcement for R.C. slab. Prototype roofs have been made where all reinforcement is of bamboo splits. It is expected that the life of bamboo reinforced concrete slabs would be 15-20 years.

5.9.4.8. Fire Resistance Treatment for Thatch

The CBRI has evolved the following types of 3 treatments for making thatch fire resistant.

(a). Chemical treatment - In this case the thatch and the binding ropes are dipped in a solution of fertilizer grade diammonia phosphate and sodium fluoride. Since this chemical is soluble in water, a water proof paint is later on applied over the thatch. The cost of this treatment is roughly equal to the cost of the untreated thatch. But the life of the thatch is increased to 5 to 6 years apart from making it fire resistant.

(b). Twisted Thatch Roof Covered With Non-Erodable Mud Plaster - In this case only the binding rope is soaked in the chemical treatment. The thatch is twisted to form ropes and tied with rope at 15 cm centres. After placing the ropes side by side on timber/bamboo frame, these are plastered on the top with non-erodable mud plaster having cut back bitumen mixed in the clay. The top of the mud plaster is again sprayed with cut back and finally white wash done on the top. This treatment has been tried on proto-type huts and the cost of the thatch is increased by about 25 percent and it can be done on self help basis with a little training.

(c). Thatch plastered with bitumen stabilised mud on top and with ordinary mud on the underside.

5.9.5. **Floors**

5.9.5.1. Soil should be well compacted & rendered dust free by regular application of mud and cow dung plaster.

5.9.5.2. After ramming the earth, this may be covered with broken stone slab pieces or with burnt bricks or with burnt clay tiles or with soil stabilised with cement, lime or bitumen.

5.9.6. Doors and Windows

5.9.6.1. Door and window shutters can be braced and batten type with locally available timber.

5.9.6.2. The door frames may be completely eliminated and the shutters may be hung with pivots.

5.9.7. Lintels

5.9.7.1. The locally available timber planks of sufficient thickness can be used.

5.9.7.2. Lintels can also be made by making frame work of bamboo.

5.9.7.3. Stone slabs of 5 cm and above thickness can also be used as lintels.

5.9.8. Finishing

5.9.8.1. Non-erodable Mud Plaster

The mud plaster is made non-erodable and water resistant by a thorough mixing of clay with bhusa and bitumen cut back. Finally a gobri leaping mixed with cut back is applied on the top of the plastered surface. This has been tried on a large number of houses in rural areas and has been found to be very effective. The treatment is to be repeated after five or six years.

5.9.8.2. Water Proofing of Existing Mud Plaster Walls

In this, a solution prepared from asphalt and kerosene oil is sprayed on the plaster surface. The solution gets absorbed in the wall thereby making it water-proof.

5.9.9. Building Services

5.9.9.1. P.R.A.I. Type W.C. Pan

The PRAI latrine is a hand-water flushed, water-seal latrine with excreta disposal to a cess-pit or bored hole. The outhouse superstructure is similar to that of the pit privy, although the squat plate is set directly onto the ground into which the toilet pan is inserted. The pan leads to a water trap and effluent line. Defecation takes place into the pan which may be hand flushed by pouring water from a cannister into the excreta undergoing anaerobic digestion. The digested sludge after one year's residence in the pit can be used as a fertilizer. During the one year digestion period, a second pit is dug and utilized. The major advantage which the PRAI latrine has over the pit privy is that it employs a water seal whereby all fly breeding in the pit and odours emanating from it are obviated.

5.10. Systems of Construction

Some of the techniques developed by the CBRI may be called systems of construction. These are:

5.10.1. Holopan System

Basically it is a framed infil type of structure where the frame consists of vertical reinforced concrete column cast in-situ between precast hollow concrete panels. The same type of hollow unit is used for floor/roof by placing it over partially precast RCC joists. This technique has been adopted for an industrial workers' housing project in Ghaziabad (U.P.).

5.10.2. Pre-Fabricated Brick Panel System

This system is based on the application of pre-fabrication of bricks. The wall panels are un-reinforced, while the roof panels are reinforced both made up of bricks. The roof panels are placed on partially precast RC joists and 25 mm deck concrete laid on the entire surface. The wall panels are 7.5 cm thick and for improving the thermal insulation, sun-dried brick walls can be built internally as a lining.

5.10.3. Skeleton System

The CBRI has developed systems of skeleton construction in which first durable support and roof is provided either of reinforced concrete or of timber or of bally. The walls, doors and windows can be put up later. The concrete skeleton system has been tried on a large number of houses.

5.10.4. Sarvatogriha

The CBRI has developed a system of making houses without using any cement and steel. In this system, the end walls are first built up to the full height of room and the side walls upto a height suitable by consideration of head room. Two identical parabolas are then drawn on the end walls and guiding lines with string/thread stretched between them. Bricks are then laid in mud mortar in alignment with the parabolic curve. This forms the wall and roof combined.

5.11. Physical Planning

It will be realized that while it is essential to reduce the cost of construction of buildings by adopting the use of new materials and techniques, it is also very necessary to pay adequate attention to the aspects of physical planning and layouts of building projects. Much economy can be achieved by proper physical planning by way of saving in cost of land, and its development. The work done in this field is described in brief in the following paras:

5.11.1. Housing Developments

Formulation of densities, optimisation of land use allocation, impact of size and shape of plots, layout patterns and cluster planning, low-rise high density housing.

5.11.2. Planning Standards

Formulation of space standards for various functions at different levels, quantification of different planning parameters in urban and regional development.

5.11.3. Standardisation and modular coordination are potential tools for effecting substantial economy in building cost, through saving in materials, labour and construction time. Some work has been done in this connection in India and has been incorporated in the relevent Indian Standards.

5.11.4. Physical Plans

Identification of growth centres. Formulation of optimum land-use-patterns, optimising location of different functions at different levels of planning.

5.11.5. New Towns

Feed back surveys of townships, physical layout v/s infra-structure cost, adoption of space standards, design guidelines for planning of new towns.

5.11.6. Planning Techniques

Development of planning models for optimum decision making, development of multi-graphs, development of mathematical equations, preparation of computer programmes.

5.11.7. <u>Economics of Development</u>

Infrastructure costs of development, optimization of overall costs, economics and financing of projects.

5.12. The construction techniques described above take into account optimisation of design, simplicity in production, transportation and erection. These are labour intensive, requiring very little capital investment. These result in saving of scarce materials, skilled craftsmen and construction time. These have already been successfully adopted in large construction project all over the country. Similarly, physical planning and layout studies have also been carried out successfully and adopted on some live projects.

5.13. The appropriate techniques for various building elements for both urban and rural buildings alongwith percentage saving in overall cost against the conventional techniques are given in a table at Annexure I.

Chapter - VI

6.0. INTERLINKAGE IN INSTITUTIONAL INFRA-STRUCTURE IN RESEARCH AND DISSEMINATION

6.1. Several recognised research institutes are at present doing useful work on building materials and building techniques. The main works being done by these institutes are:-

(1). to evolve new building materials out of locally available raw materials, hitherto unutilised,

(2). to evolve new building materials out of agricultural, industrial or forest wastes,

(3). to improve the quality of traditional building materials by making suitable modifications in the composition of raw materials or by modifications in the manufacturing process,

(4). to introduce new forms in traditional building materials with a view to effect economy.

(5). to evolve new construction techniques with a view to economise in cost and consumption of building materials by optimum utilisation of their strength.

(3). to evolve new design techniques to effect economy and speed of construction.

6.2. India is a vast country having regions vastly differing from each other in climate, rainfall, topography, vegetation, soil types, mineral resources, traditional values, social customs, etc. Hence, research has to be oriented to cover various regions and their respective requirements. Under the circumstances, a close inter-linkage is necessary between various research institutes, to avoid duplication of efforts and to supplement each others' work. Similarly, there should be greater integration between the research institutes and the building materials and construction industries. There is also a greater need for translating into practice the findings of the research institutes. For this purpose there should be more experimental and demonstrative constructions.

6.3. The research activities of CBRI are divided into the following major divisions:

(1). Soil Engineering	Foundation problems
	Soil behaviour
	Pile foundations
	Diaphragm wall
	Ground strengthening

		Test methods and equipment
		Special investigations.
(2).	Building Materials	Brick and tiles
		Cement and concrete
		Lime and lime products
		Agro-Industrial wastes
		Plastics and plastic products
		Bitumen and Bitumenious products.
(3).	Building Processes, Plants and Productivity.	Processes
		Services (water supply, sewerage and electricity)
		Plants and equipment
		Management and productivity
		Cost economics.
(4).	Architecture and Physical Planning	Space planning with reference to Housing, Health Buildings, Educational buildings, Community buildings, Physical planning, densities etc.
(5).	Fire Research	Fire ratings
		Fire behaviour
		Special investigations
(6).	Rural Buildings and Environment	Rural dwelling
		Farm buildings

		Rural water supply & drainage Mud and thatch structures
(7).	Efficiency of Buildings	Heat transfer Acoustics Ventilation Illumination Climatology Solar Energy Instrumentation
(8).	Extension and Construction	Dissemination of the results of research and information about new materials and techniques developed by the Institute. Construction of selected demonstration projects for various organisations. Feed back studies on the materials/techniques adopted in field.
(9).	Information	Publication of literature on R&D work done by the Institute. Licensing for commercial production of materials/techniques developed by the Institute.

3.4. The National Buildings Organisation, New Delhi, is also doing good service to the nation in disseminating the knowledge gained as a result of research work done by various research institutes throughout the country, through various studies and reports, literature and pamphlets and news media such as T.V., Radio, and films. The N.B.O. has also opened a number of rural wings throughout the country to extend the research findings to rural users.

3.4.1. An experimental housing scheme of N.B.O. has been started for encouraging the user agencies in trying new techniques. Under this scheme, financial assistance is provided to building construction agencies, if they take up any construction with new techniques or materials. This is getting a good response and has evoked much interest amongst the user agencies who are benefiting from this scheme and simultaneously get the benefit of learning and adopting the new techniques for their future projects. Under this scheme, all the construction agencies have been requested to earmark atleast 1% of their total funds to experimental construction. This is expected to result in increased construction activities using the latest techniques which will go a long way in large scale adopting of those techniques.

6.5. Some other research Institutes that are working for the development of appropriate technology for buildings are named below:

6.5.1. Structural Engineering Research Centre (SERC),Madras/Roorkee

The SERC has been carrying out R&D work on innovative techniques and new building materials also apart from the studies on other aspects. Some of the works related to housing which have not been covered earlier are the production technique for lateritic soil stabilised blocks with lime by special compaction device, funicular brick shell roofs, composite cellular concrete flooring system, precast reinforced concrete joist and hollow clay blocks and precast prestressed clay block floor steps and prestressed concrete channel units for large spans. The SERC is also working on the development of prefabricated service core units,water tanks,grain storage bins using ferrocement,etc.

6.5.2. Regional Research Laboratory (RRL), Jorhat (Assam)

The laboratory is engaged on the effective use and development of materials in the north eastern region of the country. Some of the materials developed are corrugated roofing sheets from waste paper, bamboo roofing element from locally available timber and bamboo,bricks, cementitious binder from paddy husk ash and flooring tiles from waste asbestos. The laboratory has also worked on common facilities and has evolved process for domestic potable water from water filter candles and a septic tank from waste bitumen drums.

6.5.3. National Environmental Engg. Research Institute (NEERI), Nagpur

Apart from several other studies and R&D work in the field of environmental engineering, its major work in housing has been towards rural sanitation. The Institute has developed hand flushed water-seal laterines which have been found to be economical and satisfactory in a large number of rural houses. The Institute is also carrying out studies on disinfection of wells in rural areas using pot chlorinators and epidemiological studies on 'Assessment of health status of rural population around Nagpur (India)'.

6.5.4. Planning Research & Action Institute, Planning Deptt.(PRAI),U.P.

The PRAI is carrying out studies in the field of environmental sanitation. It has also taken work for safe water supply in district Barabanki with aid from UNICEF. They have also taken up demonstrations for sinking hand pumps and tube wells in public places. The PRAI type latrine developed by them is very suitable for rural households.

6.5.5. The list is not exhaustive and many more Institutions are engaged in similar activities all over the country. These include educational institutes and universities, P.W.D. and other departmental research institutes in various states, and various R&D wings of Industrial Undertakings, both Govt. and Semi-Government and private. The cumulative contribution of all of these institutions is fairly large. What is needed is firstly more interlinkage between all the research bodies for exchange of ideas and avoiding duplication of work and secondly more dissemination and extension of information so that the user agencies may know what is being and has been done and how they could utilize the results of the research to their benefit. Both intensive and extensive efforts are needed in the direction to make research more purposeful and beneficial to the users and the country.

Chapter - VII

7.0. INTERLINKAGE IN TECHNOLOGICAL ASPECTS

7.1. It has been mentioned earlier that after the research is completed, it has to be extended to the user as well as to the producer of the materials and components. Hence, an effective extension wing will help in spreading the achievements of the research to the field. However, no research can be fool proof. It often happens that some of the results of research, obtained in the laboratory, do not come up to expectations in the field. There is nothing wrong with it, and it must be expected, but, it is necessary that when it happens, the research scientist should study the feed back information and modify his technique to suit the field conditions.

7.2. For this purpose, a sort of after sales service becomes essential. If an entrepreneur takes a licence for producing certain machines or materials as per recommendations of research, a close liaison is necessary between the Research Institute and the entrepreneur to attend to the teething troubles. Modifications may be required in the machinery, in the materials and equipment, in the composition of the product itself, and so on. Constant advice on all these aspects will be necessary, involving frequent inspections, studies and further research. The CBRI is fully aware of these matters and maintains a close liaison with all its licencees, or users of its techniques. Testing of materials manufactured in the factory or made at site is regularly undertaken by the research scientists. The users often want advice of the Institute in planning their projects, in deciding its design and specifications or in their execution.

Help is regularly rendered to them through various research divisions of the Institute or through its extension cells. Other research Institutes, involved in Building research, are also doing similar service to popularise the research products and to modify them, if necessary, to suit the field conditions in different climatic conditions.

7.3. Many times problems crop up either in the industry or in construction works where the executing agency or individual wants the help of research body to advise them on a specific problem or to help them in planning or executing a project, carrying out tests for certain specific activities, or overcoming certain setbacks in some of their production or construction activities. These problems may not be connected with the regular research programme or findings of the Institute, but still they are problems which need the help of a research institute. Hence, it should also form a part of the activities of such institutes to extend such help to the industry, institution or individual so that the users' faith in research is enhanced, which will in turn, result in making the new techniques more popular.

7.4. Such cases can be taken up by the concerned research laboratories as consultancy, sponsored or demonstration projects, as the case may be. Sometimes, the problems posed by the users in such projects are a real challenge and go a long way in furthering the aim of research, bringing new problems to light where research is needed and in fulfilling the common objective of research and practice viz. to progress towards the goal of "maximum benefit to maximum number". With this aim, the C.B.R.I. undertook some projects as given below:

7.4.1. <u>Demonstration & Construction of School Buildings in U.P. State</u>

The Central Building Research Institute, Roorkee had taken up research on Educational buildings with a view to provide design data on functional and educational requirements, and studying methods of cost reduction in planning and constructional techniques. The research carried out so far had shown promising results, making it possible to obtain significant reduction in the cost of educational buildings, through rational use of space, improved constructional techniques and cost planning during their design and construction.

Extensive basic research work was done on ideal size and shape of class room, optimum utilization of school spaces, functional and physical requirements and construction systems to suit the climatic conditions and available resources. Alternative proposals were drawn for construction of schools economically and efficiently in various parts of the country. After carrying out detailed investigations the institute constructed prototypes in many states. The U.P. Government wanted the C.B.R.I. to demonstrate the construction of these schools in U.P. on a large scale.

Based on its research findings, C.B.R.I. constructed about 2,500 schools in remote villages of the state of U.P. within a record time of about 3 years. This resulted in about 20% savings in terms of materials and overall cost. After completion of the construction in 1975 successfully, the technique has been adopted by other state agencies, who are continuing to build schools on the same pattern.

A feed-back survey of these buildings was also undertaken recently which indicated minor modifications in the plans originally adopted. Now the State has adopted the same pattern for future school buildings.

7.4.2. School Building Programme - Manipur

After studying the special climatic conditions terrain and limitations of available resources CBRI in collaboration with the State of Manipur prepared a scheme for construction of primary schools. The scheme provides a permanent school building skeleton. The community would later build walls as per their locally available materials and construction techniques. The system of skeleton is such that it can be erected within a week's time. About 100 schools have already been put up in the State of Manipur and about 100 more are in various stages of construction.

7.4.3. Besides the above mentioned projects, Institute also provided technical assistance to the State of Punjab, Maharashtra, Goa,Daman and Diu, Orissa and Kerala in their construction programmes of school buildings. The States of Arunachal Pradesh and Tripura in north eastern region and the Union Territory of Andman Nicobar islands have requested CBRI to provide technical guidance in their actual construction projects in order to achieve speed and economy.

7.4.4. Health Buildings

Inspired by the constant governmental efforts to improve the health facilities for rural and semi urban population scientific investigation on health buildings was also undertaken at the Institute.

The objective of those studies was to formulate space norms, design and construction gudelines for various categories of health buildings.

The investigations included an analysis of functional spaces, anthropometric and environmental conditions to fulfil the medical, teaching and physical requirements. The results were used in planning and designs of several types of buildings, such as family welfare centres and sub-centres in rural areas, hostel for field trainees, nurse and midwife training centres, district bureaus, maternity, sterilization and urban family welfare centres and urban maternity houses.

In order to create suitable infra-structure for regulating population growth, the Government of India had taken up an India Population Project in selected areas of Uttar Pradesh a couple of years back. Financed by International Development Association and Swedish International Development Authority, the project included construction of health buildings and other supporting facilities like residences for the staff and administrative offices etc. The allocation for construction was Rs.52.6 million out of the total assistance received of Rs.118.7 million. In the design and construction of these buildings studies undertaken at the Institute mentioned above, were utilized. The major programme of buildings has already been completed covering six districts of the State. Besides planning and design, construction techniques used for these buildings were developed at the Institute which resulted in substantial saving in time and cost.

Recommendations of the study on health buildings are also being utilized by a similar programme taken up by the State of Karnataka.

7.4.5. To evaluate the performance of the buildings constructed under the above programme a feed-back study was taken up recently.

The result of surveys indicate that various spatial provisions were found adequate both quantitatively and qualitatively. The surveys also indicated minor modifications in the mode and quantum of storage provisions in few building types. After the successful implementation of the U.P. Health Building Project a few other States have also shown interest in the planning, design and construction methods adopted. It is hoped that the recommendations of the Institute will be further utilised in providing health buildings for rural and semi-urban areas in those states also.

7.5. Most of the large industries have their own R&D wings where research facilities are available. Those wings are engaged in the research on the day to-day problems coming up before the industry. Some of them are doing good work, as they are closely linked with production. They also have feed-back facilities available both from the producers as well as the users. More and more new industrial establishments are going in for their own research wings, so that they can solve their problems under their own management. It is, therefore, obvious that some of these research wings of the industries will be doing overlapping research, which generally results in wastage of efforts. It is also possible that some of these industries might be doing work on the problems which might have already been solved by some of the research institutes and vice versa. Exchange of information between the research institutes and the R&D wings of connected industries will eliminate such wastage of efforts. It is, therefore, essential that a close liaison is maintained between them and even a programme of exchange of scientists between the industry and the institutes could be undertaken. This will enable the scientists of the research institutes to study various problems in the field or industries from close quarters and enable them to appreciate these to the fullest extent. Similarly the scientist from the industry will also get an opportunity to work in the research laboratory where he can up-date his knowledge about the work already done in the institute and may also be able to take advantage of the research facilities available in the institute. This mutual exchange programme and close inter-linkage between research institute and the R&D wings of industries, in addition to the sponsored or consultancy projects, will avoid a lot of duplication of work, wasteful expenditure and delay in dissemination of information.

7.6. Similarly a close inter-linkage between the research institutes and educational institutes is also very necessary. At present the teaching curriculum of the educational institutes falls far behind the latest development in the concerned fields. As these developments are taking place at quite a fast rate, a fresh engineering graduate coming out of the university feels very much out-of-date when he joins the profession. A number of new materials and techniques are unknown to him with the result that he is likely to be confused when these materials and techniques are recommended to him. He will also take a long time in learning them. If the teachers as well as the students are given a chance to visit research institutes, it will help the building activity to a great extent. The teachers would know about the latest developments and can impart this knowledge to their students in addition to the regular curriculum.

7.7. There are a number of research institutes who are at present engaged in work covering the diverse fields of activities which concern building construction and building industries. It has also been observed that some-times several of them are doing work on the same project due to which a lot of duplication of work occurs. Here also there is a scope of improvement in the working, if the various institutes remain in touch with each other. As a matter of fact such a liaison will help in mutual exchange of ideas, which may result in expeditious prediction of results of research in the various institutes. Here also mutual exchange of personnel will help a long way.

7.8. Various research institutes in India are alive to the importance of the inter-linkage with the R&D wings of the industry, other research institutes, and educational institutes. There have been constant efforts on their part to encourage exchange of information amongst each other through various symposia, study groups, refresher courses etc. There has been continuous participation of our research scientists in the research activities of the other countries also and we have our representatives on several international organisations.

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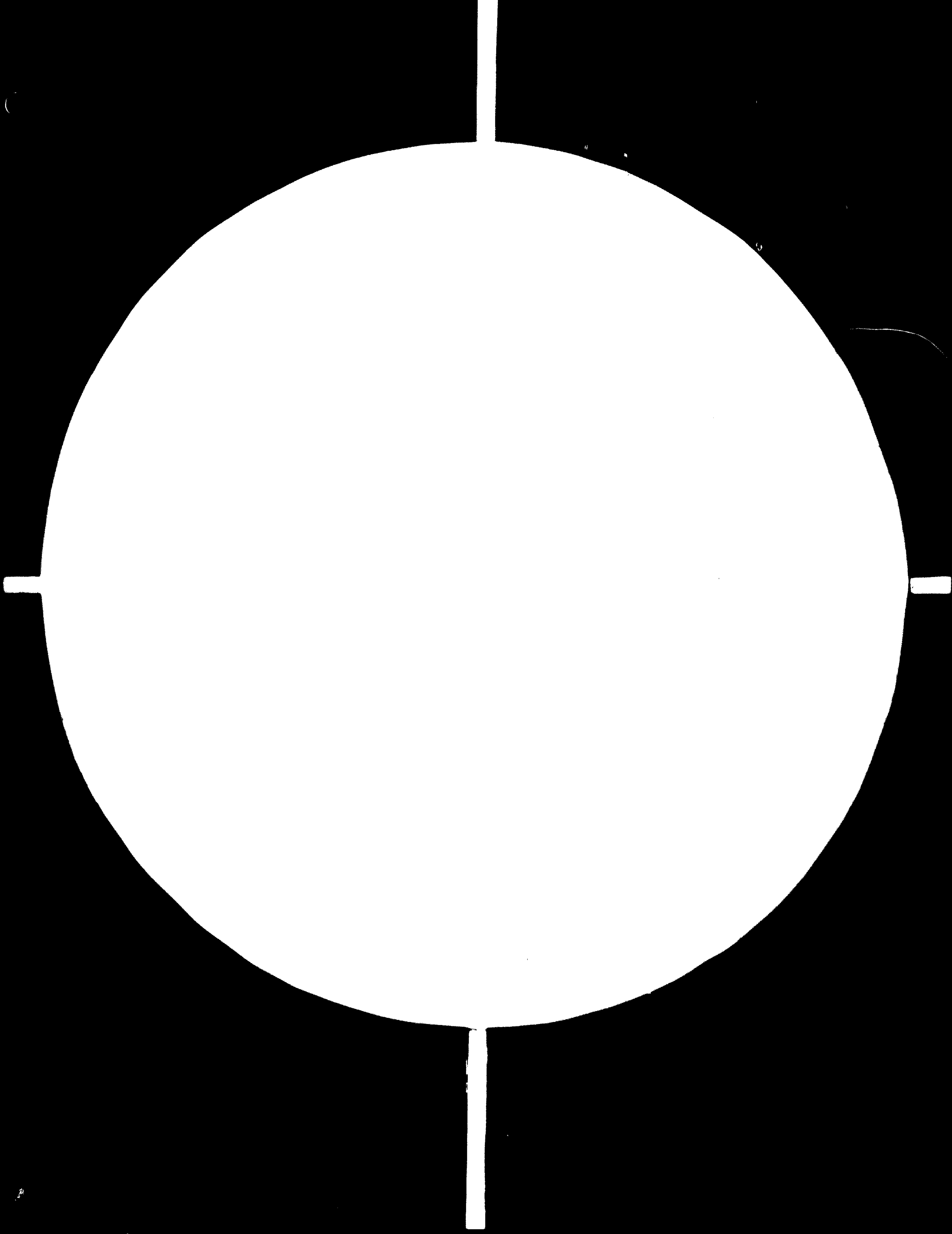

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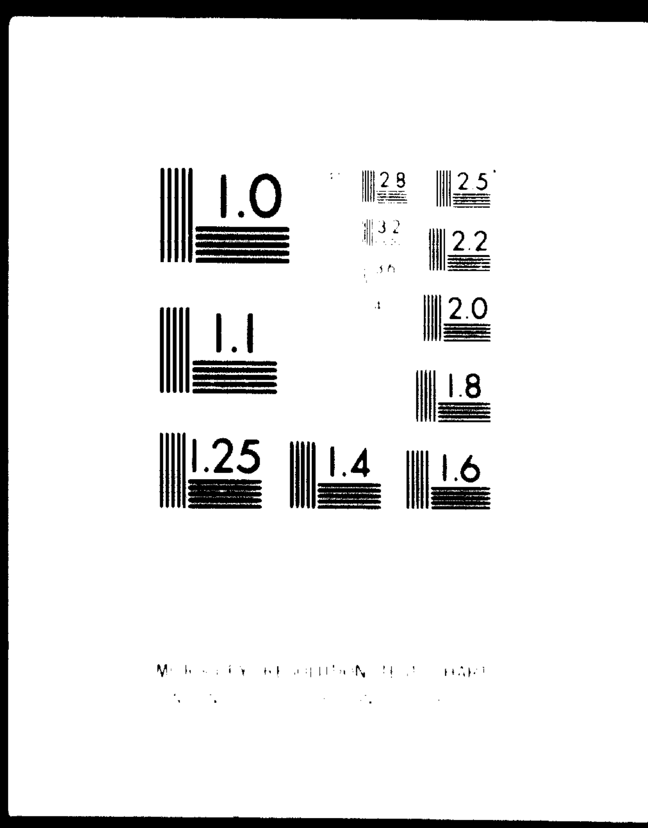

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Chapter - VIII

8.0. GUIDELINES FOR INTEGRATED APPROACH ON BUILDING RESEARCH AND INDUSTRY

8.1. To overcome the shortage of housing, there is an urgent need of continuation of R&D work in the various fields of housing activities such as the development of new building materials from materials hitherto unutilised, agricultural, forest and industrial wastes, to modify manufacturing processes of conventional building materials, to evolve new design techniques taking the optimum utilisation of the intrinsic strength of the components, to evolve simple, labour intensive construction techniques with higher productivity and to mechanise the operations which are laborious and inefficient, to evolve efficient planning and design for different types of buildings taking environmental comforts into account.

8.2. It has been observed that though quite a substantial R&D work in the above fields have been carried out, but the utilisation or adoption of the materials, techniques and processes have been very limited. All professionals have to give greater attention to the cost control in planning itself as the build up of cost starts from the conception of idea to build. It is also necessary to adopt modern management techniques in monitoring and execution of the projects. This calls for a coordinated and integrated approach between the national research organisations, the research divisions of the industry especially the building materials manufacturers and the research and testing laboratories of the construction organisations.

8.3. For achieving the above objectives, the following guidelines are suggested:

(1). There should be a coordinating committee between various research organisations comprising of the senior members and an eminent engineer/scientist should be the Chairman. The Ministry of Works & Housing or equivalent ministries of other countries could constitute such a committee.

(2). The committee should review research projects from various research organisations and decide priority. It should recommend additional funds if required.

(3). Special problems of research should be referred to the National Institutes.

(4). The day to-day problems of the industry should be tackled by the R&D wing of the industry itself.

(5). The routine testing work should be carried out by the testing laboratories of the construction department themselves. There should be more site testing laboratories set up on all works amounting to more than Rs.0.2 millions.

(6). Materials manufacturers should also have R&D laboratories and have quality control to improve upon their product.

(7). There should be a regular system of dissemination of information, knowledge and the latest findings by publications, demonstrations, lectures and symposia.

(8). The Research Laboratories should have a regular system of collecting information from the industry about the new techniques and their performance in field.

(9). In urban areas, specially in metropolitan cities, land is becoming very costly and therefore multistoreyed buildings are becoming the order of the day. Sustained R&D work is required to achieve better quality of construction in high rise buildings.

(10). The contract systems, procedures and bye-laws need to be studied and necessary revisions made so that the new techniques and systems can find application.

(11). There is a need to open more research wings for the R&D work in rural areas. They should collect statistics about the availability of various local materials, the conventional building practices and also about the habits and living pattern of the people so that R&D work can be directed to evolve systems more appropriate to and fulfilling the needs of rural areas.

(12). Major part of basic research should be handled by the technical universities and I.I.Ts.

(13). Applied research should be mainly carried out at the national laboratories.

(14). The construction-organisation-laboratories should concentrate more on testing work and in solving day to day problems that may be experienced in the industry.

(15). There is a need to carry out method studies on building operations to increase productivity and reduce wastage.

Arrangements for imparting training to craftsmen need to be studied and a building construction industry training board should be set up to bring up skilled craftsmen in different trades in the same way as of engineers and supervisors from the universities, colleges and polytechniques. Although industrial training institutes are in existence, but so far as the building industry is concerned, these have not made much impact.

(16). The building industry should be given an incentive to provide housing by way of reduction in rates of interest from banks and in recovery from the client/user the period should be made such that easily payable instalments are made.

(17). The benefit of the R&D efforts should go to the user also rather than only to the material or components manufacturer/supplier.

(18). Large number of factories for small prefabricated building components and materials should be established, based on R&D work.

(19). Type plans should be prepared, based on survey and R&D work for different types of buildings in different regions, and Governments concerned should follow these typical plans for at least 5 years.

(20). The construction organisations should earmark funds upto

1 percent for making up prototype demonstration projects adopting the new materials and techniques developed by R&D work.

(21). There should be exchange of personnel from the research laboratories to the construction organisations and vice versa so that the research staff can study the actual problems in field and come out with more practicable and appropriate solutions. Similarly the construction staff should carry out some R&D work on the problem faced in field.

(22). In rural areas, the emphasis should be on local materials utilisation. Techniques should be so developed that they can be worked on self-help-basis. Technical assistance and guidance, tools and equipment should be made available in the initial stages.

Chapter - IX

9.0. NEED FOR A NATIONAL POLICY - SUGGESTIONS AND RECOMMENDATIONS

9.1. In the foregoing chapters, we have studied the various problems facing the building construction and building material industries; efforts made through R&D to solve some of the problems by evolving new materials and techniques; and to utilize locally available materials and industrial and agricultural wastes for producing alternative materials in place of the traditional ones. A lot of efforts are being made by various research institutes in this direction, however, much remains to be done in this direction.

9.1.1. Though a lot of work has been done by the research institutes towards evolving appropriate technology and materials suited to the country's need, yet its full impact has not been felt in the construction and production activities. Some of the reasons are given below:

- Lack of dissemination of information about achievements of R&D amongst the user agencies.
- Inertia on the part of user agencies towards use of new technology and materials.
- Inbuilt fear in the minds of the users about the suitability of new techniques in the field.
- Lack of appreciation of the problems of the users by the research scientists.
- Lack of feed back from the user of new techniques or producer of new materials to the research bodies.
- Lack of incentive for use or production of new materials or techniques.

- : Lack of demand for new materials.
- : Lack of training of the field personnel, from the skilled workers upto the engineer, in the use of new materials and techniques.
- : Non-availability of sufficient information and literature on the latest innovations.
- : Putting out half baked techniques to the users, unsuitable for actual use in field. It results in loss of faith by the user in new techniques.

9.2. To overcome all these hurdles, it is necessary to have better interlinkage between the research bodies and the user agencies. This aspect has already been dealt with earlier. Intensification of extension activities, close inter-laboratory-industry, inter-laboratory-university and inter-laboratory ties between different research laboratories are most essential to overcome some of the factors, enumerated above.

9.3. To achieve the aim of large scale adoption of appropriate technology, suitable regional as well as a national policy are a must. Without that, various constraints inhibiting the use of new materials and techniques by the common user as well as by the public sector agencies cannot be removed and much of the efforts made by the R&D organisations and research bodies will continue to be wasted. Both regional and national policies should have a close interaction to meet the socio-economic needs of the masses. They should ensure adequate employment opportunities, greater income generation and improvement in the conditions of life in the country. However, before making suggestions for the regional or national policies, a few more facts have to be considered in details.

9.3.1. It is obvious that the production level of all building material industries has got to be increased to a large extent, in order to achieve our targets of building construction. For this, a more comprehensive developmental and industrial strategy designed to meet basic socio-economic needs and to achieve adequate growth of technological capability in developing countries is needed. It is true that in certain key industries, like steel, machinery and equipment, fertilisers and petro-chemicals and the like, we need sophisticated technology and know-how. Yet, we have to see how far the developing countries are justified in adotping the general pattern of industrial growth and the structure of industry, which are being followed by the industrialised and affluent nations. In developing countries like India, there are growing misgivings on this point as to whether this is wholly appropriate to meet our basic socio-economic and technological needs.

9.3.2. It will be seen that the modern industrial sector constitutes only a small fringe in most of the developing countries and the benefits in terms of income and employment have been restricted to a very small section and have not percolated to the poorer sections, mostly resident in the rural areas. On the other hand, they have resulted in migration of rural population to urban areas, resulting in creation of slums and other related problems. It is, therefore, imperative that the benefit of industrialisation should be extended to as wide a section of the population as possible. Though some heavy industries will have to be capital intensive, with sophisticated technology and manufacturing know-how, a very large area of manufacturing can be identified where these constraints do not exist. It is in respect of this significant production sector that decentralization and location of production units away from industrial centres hold out significant possibilities. The building material industry has a great potential in this respect. In chapter III, we have identified such industries, which can be decentralized and located in the rural areas or in small towns.

9.3.3. By locating these industries nearer the villages, we will achieve manyfold benefits such as:

(a). The socio-economic benefit of the industrialization will reach a wider section of population, mainly to the rural poor.

(b). The migration of population from villages to towns will be arrested. This will reduce the problems of over population in towns which will in turn reduce the housing problem and creation of slums. It will also improve the quality of life in the rural areas.

(c). By using locally available materials and improved designs, the cost of production will be lower, resulting in reducing the cost of buildings. This will also save scarce building materials such as cement and steel for other works where their use is essential.

Thus, such decentralization of industry, and bringing it nearer to the rural consumers, should form an important part of the regional as well as national policies of the developing countries.

9.3.4. Another important point is about the construction of buildings in rural areas. It has been brought out earlier in this paper that the housing needs of rural areas are gigantic and if we try to solve them by using the pattern of urban housing, we will not be able to make even a sizeable dent in the problem, mainly for three reasons:

: Lack of sufficient building materials

: Lack of skilled personnel and labour

: Lack of financial resources

Due to this a different technology has been suggested as appropriate for rural areas, using local material and techniques, with suitable modifications to improve the quality of construction. The concept of aided self help is also very appropriate to the rural scene.

9.3.5. Some well meaning sources have objected to this approach. They have raised the question whether the rural population are considered to be second rate citizens, for whom only second rate specifications are suggested. This doubt is based on the erroneous impression that the specifications suggested for rural houses such as walls of sun dried bricks or mud plastered bamboo jaffri, thatch roof etc. are inferior specifications.

9.3.5.1. All over the world, the rural housing techniques are markedly different than the urban housing. In the earlier times when the rural society in India was comparatively more affluent and the urban housing techniques were also well known to the rural population and rural artisans, the houses in the rural areas continued to be different than in the cities. Why was it so ? If we go deep into the question, we will find the reason for this difference.

9.3.5.2. The pattern of living in the rural areas is different than in the cities. A city dweller needs housing space for a very limited number of activities. Hence, he can do with a small house sufficient to accommodate his essential belongings, a roof to sleep under and to do various household chores, such as cooking, washing etc. On the other hand a farmer in the rural area has to store the products of his farm, seeds and the fodder for his cattle in the house. Again he has to store his farming implements and other equipments which require a good amount of space. The cattle and poultry have all to be housed for whom he needs a lot of indoor and outdoor space within the compound of his house. The social customs require the house to be divided into two or three separate areas viz. the portion for the use of women folk, the portion for the menfolk, and the portion for farm implements, storage and cattle. Apart from these, the rural areas are deprived of many sophisticated facilities for cooling or warming their houses. Thus, for summers, during the day time the house has to remain cool and during nights, they need open yards for sleeping. In winters also the house must have adequate thermal insulation to keep warm during the cold nights. Thus the covered and open area required by a rural householder will be many times more than that required by an urban householder. The specifications for construction will also have to be different in view of the different specific needs of the villager. Naturally for such bigger houses the requirement of materials will be much more and if they are constructed with the urban techniques, the cost will be very high. Existing pattern of housing in the rural areas is a result of experience gained through hundreds of years. What is required to improve the quality of the rural housing is to make improvements in the existing techniques and improve their environments like road, drainage, sanitation etc. Adoption of appropriate techniques suitable for rural areas should form part of the regional and national policy and these will be different than the specifications for urban housing. These are, however, in no way second rate but are only appropriate specifications for the specific needs of the rural householder. On the other hand they may be useful even for urban areas if constraints of space and availability of materials are not there.

9.4. Considering all the points brought out earlier, the following suggestions are made for incorporating in the regional as well as national policies for the advancement of appropriate building technologies and production of materials to solve the gigantic housing problems being faced by the developing countries in general and India in particular:

(a). Cheaper buildings should be provided by organising the supply of materials and by acting pursuing research into schemes of cutting down the cost of construction.

(b). A National Building Finance Corporation should be established to promote the organisation of mass production of cheaper building materials from local resources through appropriate technology.

(c). The private sector should mobilised and encouraged in standardisation of building components, and their manufacture on large scale.

(d). To meet the demand for various building materials, a comprehensive policy for their production and proper use has to be adopted and pursued. Some suggestions for the same have been incorporated in para 3.9 of this study.

(e). Research in the design of low cost housing models to meet the needs in different regions of the country should be sponsored and promoted.

(f). For rural buildings, materials and techniques appropriate for rural areas should be evolved and adopted.

(g). Government construction in rural areas must adopt the same techniques as are advocated for large scale use by the rural public. This is one single factor which can reorient the entire rural construction programme, resulting in saving of costly building materials and educating the rural masses in adoption of techniques appropriate for rural areas.

(h). Technical guidance, assistance in procurement of materials, training of skilled workers for specific jobs, and comprehensive plans and specifications should be made available to individuals and cooperative societies.

(i). To make the training of building trade craftsmen more attractive adequate incentives should be given to the trainees. Such training should include training in the use of new building materials and techniques developed through research.

(j). Research organisations should continue their efforts to improve quality of bricks and to evolve new types and designs of kilns with a view to reducing the cost of bricks. At the same time, brick industry should be moderated to utilize more and more the results of research already carried out.

(k). Quick growing trees and bamboo should be planted regularly to start yielding timber for building work in the quickest possible time, specially for rural areas.

(l). Use of lime should be popularised and hydration plants should be installed in various parts of the country for production of good quality hydrated lime.

(m). Before adoption of new techniques, pilot studies, in laboratories, experimental construction, evaluation of performance and preparation of code of practices are necessary. Adequate funds should be provided to various research institutes as well as to construction agencies for this purpose.

(n). **At least upto 1% of construction funds** of all building agencies of the public sector should be utilised for experimental projects.

(o). Planning, scheduling and monitoring of projects by net work techniques should be given greater emphasis to minimise wastage of materials, apart from other advantages of saving on cost and time.

(p). Housing should be included in the core sector of national planning programme and housing and building activities should get the priority that they deserve.

(q). The building industry should be given an incentive to provide housing by way of reduction in rates of interest from banks and in recovery from the client/user the period should be made such that easily payable instalments are made.

(r). In all government programmes of large scale building construction, suitable building materials & techniques developed by the research institutes should be adopted as much as possible.

(s). The building codes and bye-laws as existing to-day should be modified so that they help the adoption of appropriate technology.

9.5. Cooperation with Developing Countries

(i). Industrial market economies with 20% world population account for 2/3 of World's production. Lima Declaration envisaged 25% of world production in developing countries by the year 2000. This would essentially need increased cooperation among developed and developing countries and more so amongst developing countries themselves. This will apply to Building Industry as well.

(ii). The developing countries should start identifying areas of cooperation, coordinating R&D, exchanging technical personnel and communicating results. Transfer of technology amongst developing countries is very important and crucial.

(iii). India has already been extending assistance to developing countries in the field of Building Industry in areas like techno-economic and feasibility surveys, preparation of project reports, training of foreign personnel, exchange of scientists, deputation of experts, setting up of common facility centres etc. These efforts should be further increased.

(iv). In some cases, research institutes have taken up consultancy jobs for works of special nature in developing countries and have successfully implemented them. For example the use of under-reamed pile foundation for 130 KV transmission towers in about 70 Kms length in Dubai was taken up by CBRI as a consultancy project which has since been implemented successfully. Similarly, a consultancy project was undertaken by the CBRI for UNESCO Regional Office for Education in Asia, Bangkok, Thailand for "Design Guide Lines for Hostels for educational institutes for Asian Countries". More such projects should be encouraged.

(v). A Technological Data Bank needs to be established for co-operation among developing countries.

9.6. It is hoped that by incorporation of the above suggestions in the Regional and National Policies, the goal of solving our problem of housing and building shortage will come much nearer.

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Annexure - I

Table Giving Appropriate Techniques for Various Building Elements and Percentage Saving in Overall Cost Against Conventional Techniques

Building Element	Conventional Techniques	Appropriate Techniques	% saving in cost	Remarks
1.	2.	3.	4.	5.
I. Foundations	i). Spread footing	i). Under-reamed piles	20 to 50	In black cotton soil & loose strata
	ii). Raft	ii). Bored compaction piles	30 to 50	-do-
		iii). Hyperbolic parabolic shell foundation.	10 to 15	In loose soil for columns.
II. Walling	Load bearing i). Brick masonry ii). R.C.columns with in fill panels in brick/block masonry. iii). Hollow block masonry.	i). Calculated or designed brick masonry in: a).Composite mortar. b).Lime mortar. c).Lime base products mortar.	Upto 20	
	iv). Random rubble masonry.	ii). Precast stone masonry block walling.	16	Against random rubble masonry.
		iii). No. fines conc. blocks.	10	In areas where bricks are of poor quality & sand not available.
		iv). Cellular conc. blocks/panels.	15	In areas where bricks are of poor quality & stone not available.

1.	2.	3.	4.	5.
III. Doors and Windows	i). Teak, deodar frames & shutters	i). Steel frames	5 to 10	Against timber frames
	ii). Flush shutters of plywood	ii). Magnesium oxychloride frames.	15	-do-
		iii). Panelled or braced and battened shutters.	5 to 30	Against conventional & flush shutters.
IV. Lintels	Insitu RCC lintels	i). Flat brick arches.	20 - 30	Where good quality bricks are available.
		ii). Stone slabs.	20 - 30	Where stone slabs are available.
		iii). Thin precast R.C. lintels.	50	Against in-situ R.C. lintels.
V. Floor/roof	i). In situ R.C. slab and beam ii). In situ RB or RCC slab	i). Prefab reinforced brick concrete panels resting on partially precast joists.	33	Against in-situ RB slab.
		ii). Funicular shell roofing	20	Against in-situ RC slab.
		iii). Structural clay units of joist and filler type and of panel type.	25	-do-
		iv). Clay tiles and RCC battons.	20	-do-
		v). Precast cellular conc. units resting on RC joists.	30	-do-

1.	2.	3.	4.	5.
		vi). Precast RC Channel units	20	Against in-situ RC slab
		vii). Procast corod units.	8 - 10	-do-
		viii). Precast RC planks resting on partially procast joist.	25	-do-
		ix). Precast battons and hollow block fillors	5	-do-
		x). Procast RC 'L' Pan for sloping roofs.	5 to 10	Against A.C./G.I. Shoot roofing
		xi). Precast waffle units	10 to 15	Against RCC beam and slab construction.
VI. Finishing	Comont mortar	i). Composito mortar	5 to 15	Against conont mortars
		ii). Lime mortar		
		iii). Lime baso product mortar.		
VII. Servicos	Two pipe systen	i). Single stack systom of plumbing	54	
		ii). Modifiod ono pipo systom	35	For buildings 10-12 storoys

RURAL BUILDINGS

Building Element	Conventional techniques	Appropriate Techniques	
1.	2.	3.	4.
I. Foundation	Rammed earth and mud walls	i). Burnt bricks or random rubble or laterite blocks in lime mortar.	Longer life
		ii). Boulders, gravels, kankar with morrum properly compacted.	-do-
		iii). Stabilized soil blocks with cement, lime or bitumen.	-do-
II. Damp proof course	Not provided	i). Burnt bricks soaked in soap.	-do-
		ii). Burnt bricks dipped in coal tar.	-do-
III. Walling	i). Mud walls ii). Bamboo fabric iii). Tin sheets etc.	i). Locally available burnt bricks in mud mortar with water proof mud plaster	-do-
		ii). Sundried bricks in mud mortar with water proof mud plaster	-do-
		iii). Split bamboo jafri, reed panels or palmyrah leaves cladding over timber or ballies frame work.	-do-
IV. Roof	i). Thatch roof	i). Flat roof of wooden joists or ballies or bamboos having country wood planks, reeds, bamboo mat covered with compacted soil and top plastered with bitumen mixed mud.	-do-
		ii). Stone slabs resting on walls or timber joist.	-do-

1.	2.	3.	4.
		iii). Balley or bamboo truss covered with thatch, reeds, palmyrah leaves, country tiles, slates.	Longer life
		iv). G.I./A.C. Sheets with wooden ballies.	-do-
		v). Corrugated wood wool or coir boards with timber purlins.	-do-
		vi). Asphaltic roofing sheets with timber purlins.	Suitable in areas where temperature in summer is below 45°C.
		vii). Bamboo crete	Against in-situ reinforced concrete slab (steel reinforcement).
		viii). Thatch with fire resistant treatment.	Life increased by 3 to 4 times.
V. Floor	Rammed earth and gobri leaping.	After ramming earth, cover with broken stone slab pieces or burnt bricks or clay tile or with soil stabilised with cement lime or bitumen.	Longer life
VI. Door & windows	Local wood, shoots	i). Braced & batton type of seasoned secondary species of timber.	-
		ii). Pivotes for hanging shutters and no frame.	-
VII. Lintels	Bamboos, timber planks, stone slabs.	i). Locally available timber planks.	-
		ii). Bamboo frame work	
		iii). Stone slabs	

1.	2.	3.	4.
VIII. Finishes	Mud plaster -	Non-erodable mud plaster	Longer life
IX. Services	Most houses do not have	PRAI type WC pan with soak pit	-

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