OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche

08559

Distr.
LIMITED
ID/WG. 282/82
10 October 1978
ENGLISH

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

INTERNATIONAL FORUM ON APPROPRIATE INDUSTRIAL TECHNOLOGY

New Delhi/Anand, India 20–30 November 1978

WORKING GROUP No. 5

APPROPRIATE TECHNOLOGY FOR THE PRODUCTION OF CEMENT AND BUILDING MATERIALS

CASE STUDY OF BUILDING MATERIALS AND BUILDING TECHNIQUES FOR RURAL AREAS

Background Paper

78-6965

CASE STUDY OF BUILDING MATERIALS AND BUILDING TECHNIQUES FOR RURAL AREAS

by

The Appropriate Technology Development Association*
(ATDA), Lucknow

* This paper was prepared by M.K. Garg on behalf of ATDA.

The description and classification of countries and territories in this document and the arrangement of the material do not imply the expression of any opinion whatsoever on the part of the secretariat of UNIDO concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries, or regarding its economic system or degree of development.

The views and opinions expressed in this document are those of the author(s) and do not necessarily reflect the views of the secretariat of UNIDO.

Mention of firm names and commercial products does not imply the endorsement of the secretariat of UNIDO.

The document is reproduced in the form in which it was received and it has not been formally edited.

The traditional rural houses built in India generally, could be divided into the following categories :-

1. Simple huts from bamboo and grass,
2. Mud walls with sloped thatched roofs or roofs covered with red clay tiles,
3. Super-structure built by mud or sun-dried kuchcha bricks in mud mortar, roofing built up with rough wooden beams covered with thin mud paste and compact mud, kuchcha compact earth flooring,
4. Pucca house superstructure built in baked bricks in lime mortar, roofing with good quality standard timber beams with wooden planks and lime-concrete top. Flooring with lime-concrete.

Practically all the material for constructing the above mentioned kind of house was available nearby the village. The clay was dug many times at the site or transported from village pond. Kuchcha (unbaked) bricks were moulded near the village-pond from the clay and after drying they used to be transferred to the house site. The thatch for roofing purposes was usually available within 10 - 15 miles radius. Rough wooden beams were used to be prepared from the trees, growing around the village while standard wooden beams were obtained from urban area. The labour was partly employed from the family itself and partly engaged from the village for building the house. Some times specialised labour was employed on barter basis.

After independence, the position gradually changed. As the trees were cut down there was shortage of timber in villages and wood has to be imported from urban areas and paid for in cash. Due to intensive agriculture, those lands where thatched material used to grow wild, were put under plough and thatch became costly. The system of payment in kind was changed to payment in cash.

The land near about the village pond was put under agriculture and it became difficult to get clay free for house construction.

Pucca (baked brick) type rural houses were very few and could be built only by landlord and rich traders in villages. The bricks used to be manufactured by a traditional artisan class in nearby town. The fuel used was village and town refuse. The lime mortar was prepared at the site by another class of traditional artisan from the locally available calcareous material called 'Kankar'. Thus all the material was locally available and within reach of the house builder.

Before the abolition of Zamindari system in India the ultimate ownership of the village building site was vested in Zamindar and the houses remained kuchcha (unbaked & earthen). As soon as the farmer shifted to other location the building site reverted back to the Zamindar. If some one wanted to build a pucca house he had to purchase the land at a very high price and many times because of administrative and social reasons, the Zamindar did not like to sell the land to the villagers or give permission to build pucca house.

The cost of traditional house construction increased in higher proportion than the general cost rise of other necessities. The major factor in cost escalation was roofing. The flat wooden beam or even tile roofing require a good amount of timber whose cost rose steeply due to nonavailability of wood in villages.

In urban areas the technique of re-inforced slab roofing was developed in place of re-inforced concrete slab roofing. Many times when supply of cement and iron was easy the re-inforced brick roofing was found only moderately costlier than the traditional flat timber roofing or even tile roofing. This technique began to find acceptance by villagers for building houses. This kind of roofing is not stable on mud walls and therefore there was a gradual shift to build the superstructure with baked brick in mud mortar.

Another reason for shifting of the trend to pucca houses was that the ownership of a pucca house was taken as status symbol in village social circles. So after independence, villagers preferred to make pucca house rather than improving his kuchcha house. The house construction was taken up after the harvest on the income obtained from a good crop. Many time when the income was not sufficient the house construction was completed even in 2-4 years' time. The farmer will purchase bricks after one harvest, construct a part of the house after the next harvest. In this way, in 2-3 years' time, the pucca house was completed.

The various types of traditional house described above cost Rs.3/- to 7/- per sq. ft. while the pucca house of the above type cost Rs.25/- to 30/- per sq.ft. Thus, there was a big difference in the cost of construction and only well-to-do villagers could undertake the construction of the pucca house and the rest lived in their traditional earthen or mud brick shabby houses.

Various research bodies, both Government and non-government, tried to find solution of reducing the cost difference so as to accelerate the house construction in rural areas. This work could be divided in the following categories :-

1. Making kuchcha house more stable,
2. Developing low cost building material,
3. Developing low cost building technology,
4. Degrading construction specifications at the expense of stability of the house,
5. Reducing the floor area per person,
6. Flat type of multi-storey construction.

1. Making kachcha house more stable - There were two kinds of development in this field - (i) evolving a weather-proof plaster for mud walls and (ii) developing fire-proofing technique for thatch. The mud walls get eroded in rainy season and every year they have to be repaired and re-plastered at the end of rainy season. Water proofing the plaster on the mud wall saved the annual repair. The

thatch is liable to catch fire, specially in summer season. By making it fire-proof, the fire hazard is reduced. But both these techniques have not been accepted in spite of demonstration and extension efforts. The villagers look to the house not in terms of 3-5 years but in terms of 50-100 years. These techniques only made houses slightly more stable but did not improve it much otherwise.

2. Developing low cost building material - The alternative building material developed were (a) cement-concrete blocks, (b) stabilised mud blocks, (c) various kinds of boards from local agriculture waste and thatch, (d) pre-fabricated components.

The cost difference between these new materials and that of the easily available baked bricks was marginal and that too is special localities. The various kinds of boards do not give stability and they require costlier finish after being put in the house. The overall cost of using the boards was therefore higher than the baked brick walls. The advantage which the insulation boards offered was not the urgent need of the villager because mostly they lead an outdoor life. No organisation for making pre-fabricated components was set up in the village. It was thus out of reach of a villager to procure these components and to manufacture them himself was definitely beyond his capacity.

3. Developing low cost building technology - The low cost building techniques were developed mortor for roofing and super-structure. The roofing technique were dependent either on making special kind of baked material from the local clays from which the baked bricks are manufactured or on cement concrete. The cost difference was not high enough to attract the villagers to the new technology.

The new type of super-structure developed was baded on a skeleton system. The roofing was put on R.C.C. or R.B. pillars or even on wooden beam and inter-spaces were filled by either mud walls or outside with baked bricks and inside kuchcha un-baked bricks.

The acceptability of this technique was again absolutely nil on the part of private individuals in villages because it did not meet the demands of aesthetic sense. Neither the safety factor was up to the requirement of the villager nor any convincing reduction of cost was demonstrated.

4. Degrading construction specifications at the expense of stability of the house - The degrading of specifications consisted of (a) economies on foundation by reducing the foundation breadth thickness and lowering the richness of the concrete mix, (b) reducing the thickness of the wall. The outside wall was reduced from 13½" to 9" and internal walls from 9" to 4½", (c) utilisation of lean cement-sand mortar, (d) economy in the R.B. slab roofing.

It will be interesting to note that the villagers have already adopted such kind of degradation of specification on their own. But they went too far. The walls and roofing developed cracks. The floors and plasters started to wear off. The heat load is too high making the house uncomfortable to live in during summer months. The house started looking shabby in 3 to 5 years' time. But due to the economy in cost, such houses are still being built.

5. Reducing the floor area per person - The living space per person was reduced from about 100 sq.ft. to about 50-70 sq.ft. The width of passages and moving space were reduced. Bunker type of shelves were provided in the rooms. These efforts were useful somewhat in towns whereindoor living is prevalent and which require more living space of 150-200 sq.ft. per person. This sort of construction lowered the requirement of living space, and was thus economical from town point of view. In villages already there was economy in living space because of outdoor living trend.

6. Flat type of multi-storey construction - Probably the only low cost housing which has proved effective in reducing the cost is the multi-storey flat type of housing. By building such houses, the cost of house per family was reduced by about 20-30% but such housing was possible only in urban areas, that too not on individual basis but under government or cooperative housing programme. It may also be noted here that the basic cost of construction is not actually reduced. The cost reduction is the result of many common facilities and economy in providing sanitary and community facility.

A list of various research and development work done in low cost housing for rural areas is given below.

1. Pre-fabricated brick slab for roofing with concrete beams,
2. Design of houses requiring no cement or iron,
3. Development of waterproof plaster for kachcha walls,
4. Development of a solution to make the thatch fireproof,
5. Development of certain implements to increase the out-put of the masons, thus reduce the cost of construction,
6. Pre-cast blocks with low content of cement,
7. Improvement in lime mortar so as to give it quick setting property,
8. Developing techniques for good quality bricks from inferior soils,
9. Development of idea of concrete skeleton system,
10. Pre-fabricated building components.

A perusal will indicate that some of them really could be efficient. But lack of infrastructure to supply these facilities to rural areas and a proper action technique was lacking. Whatever houses on these lines were built up in rural areas were on behalf of the Government or local bodies. The villagers generally were not involved in such techniques. If the personal involvement of a villager could be ensured by giving incentive for building their house by the new technique, some of them could have found acceptance.

The Planning Research and Action Institute took up a programme of village replanning in Etawah district of Uttar Pradesh in the year 1958-62. The whole problem of type of houses to be built was discussed with the villagers. The villagers insisted that houses with baked-bricks and R.B. slab roofing with cement flooring should be constructed. No other type was found acceptable to them. As the cost of such house could not be within the reach of each member of village community, the P.R.A.I. decided to subsidise the programme by meeting the capital cost of Blum type brick-kiln and provision of slack coal as fuel for firing the bricks required for the programme. The villagers were asked to mould their own bricks and fire them in the kiln. The villagers, therefore, could get the bricks only by spending labour and no money was required to purchase them.

At that time cement was not available easily. It was made available to them on controlled rates which also saved them a lot of expenditure.

A master plan to remodel the village was prepared by P.R.A.I. through their own staff and technical guidance and supervision was also provided free. The villager provided most of the labour required for house construction by them, only engaged special labour for part of the work. They utilised their old doors and windows and other such fixtures. Three willaves were completely rebuilt on the abo basis.

A review of the quality of the house constructed after about 5-6 years brought out the following facts :-

(1) A tendency of sinking of the wall was observed which was probably due to the utilisation of poorly baked bricks in the foundation in place of strong concrete foundation.

(2) There were some cracks observed in many R.B. slab roofings probably due to sinking of the walls as well as not providing proper centering and inadequacy of reinforcement and use of loan mortar with a view to economise on the cost.

(3) The heat load of the house was found higher than that of traditional village houses. The reason appears to be that 9" outside wall has been used instead of 13½" wall and thickness of the roof was also much less.

(4) Cement flooring showed signs of wear and also developed some cracks. Here again the reason appears to be proper floor specifications were not followed and a lean cement mix was used.

The Rural Industry Section of the Planning Research & Action Institute analysed the problem and came to the following conclusions :-

(1) Low cost houses could be provided only when the cost of the basic construction and building material i.e. baked bricks and cement could be reduced in the village.

(2) Inspite of providing specifications and guidance the villagers will have a tendency to economise in foundation, superstructure and roofing etc. Therefore, it is necessary to evolve techniques which do not leave the option of lowering of the specifications to the villagers and yet provide some economy than the standard specification.

Reducing the cost of basic building materials

BRICKS - The baked bricks used to be manufactured, as already stated, by traditional artisan class by utilising the town and village refuse. Baking of the bricks was carried out in open type of kiln which are constructed permanently on one site. A layer of bricks was placed over which a layer of town refuse was put and in this way a

a certain height was built up. Fire was started. It was a slow firing technique and it took about a month or two to bake the bricks. The work was simultaneous i.e. one side of the clamp-type of kiln was under fire, the other side was cool and yet another side was being loaded. There was no inter-relationship in the various stages.

After the brick was taken out the ash was left to be on the same place and next firing was done over it, thus giving a high hillock sort of appearance to the site. Because of slowed firing the size of the bricks was kept small and specially thin because of difficulty of heat penetration. Most common size was 4" x 3" x 1" thick. This required a lot of mortar and the construction labour cost was high. Gradually the size was increased to 7"x4"x1 1/2".

Hoffman type of continuous brick kiln was first introduced in India somewhere in 1860s and fuel used was wood. The kiln was oval shaped structure divided into 12-16 compartments with central high chimney. The compartments were permanently roofed. The investment cost was high.

, The design was developed for countries where rains are too frequent throughout the year. In India the brick making is taken as a seasonal industry carried out in non-rainy season from October to April. Kiln design was, therefore, modified to a design called Blum type. The same principle was followed.The oval shaped structure was kept but the permanent compartments were removed. No roofing was provided. In effect, it became an oval shaped tunnel The permanent chimney was replaced by moving iron chimneys. The various compartments were artificially built at the time of loading and the chimneys were placed on the compartment and gradually moved with the fire. Fuel was changed from wood to steam coal dust. These kilns gradually replaced all other kind of brick manufacture and now it is standard piece of equipment. The size of the brick was also changed to 9"x4 1/2"x3" which reduced the amount of mortar needed for construction as well as cost of construction.

A mason could place more bricks of the new size than the small bricks of the previous size. This kiln was placed near the urban areas but now has gradually spread to rural areas. The industry is owned by city entrepreneurs who establish such a kiln between a group of 40 to 50 villages. Capacity of these kilns is to manufacture 4 to 5 million bricks in a season and many times when demand is high the capacity is raised to 8 millions also. The industry suffers with chronic shortage of coal for firing. The transport cost of coal has risen very high recently, raising the cost of bricks. These kilns are centrally located and the farmer has to cart the bricks to the building site

The cartage cost of the bricks to the individual village amounts to 25% to 33% cost of the bricks. Moreover, the profit margin of the urban entrepreneur is on the higher side. If it is possible to develop a smaller kiln yet keeping the fuel efficiency which can be owned and operated by the village potter, the transport cost will be practically eliminated and overhead cost and profit margin of the village potter will be lower than urban entrepreneur. Thus the bricks can be about 30% cheaper to the villager if manufactured by the village potter. Search for such designs was carried out. Mr. Mukat Singh, Director of Amarpur Kashi Village Development Scheme has built such a kiln. It was decided to observe its working and collaborate with him. The kiln did not succeed because of certain technical reasons. Efforts to remove these handicaps were made but nothing concrete came out. The idea was not further followed. It is worthwhile if this idea could be taken up which will really help to reduce the cost of construction in villages.

Lime Mortar & Cement

The traditional binding material was lime mortar. It was prepared by burning widely spread local deposit of 'kankar' in an open type kiln. The fuel used was cow dung. Lime was prepared at the site and was wet grinded by bullock power and used. In some places where limestone was available it was burnt and slaked in water. Sandy loam clay was burnt separately and then

mixed with slaked lime solution. Lime mortar takes about 3 months to develop the strength; even then its strength is lower than that of Portland cement. Portland cement is easy to use. It started replacing the lime mortar and nowadays, except in the case of shortage, the usual preference is for the use of Portland cement. The cement is made in large-scale installations and the transport, packing and distribution costs raise the price by 30% to the villager.

CEMENT - Apart from rural housing programme, the Planning Research & Action Institute was already considering the development of 25-ton vertical shaft kiln cement plant based on utilisation of local raw materials. The details of this work is given in a separate case study submitted. During operation of this project the villagers were supplied unpacked cement which was taken by them in their bullock-carts. There was certain other reduction in the cost like the transport equalization factor and the distribution cost. The cement was thus made available to the villager on about 26% lower price. The cement project showed a lot of promise but its technical feasibility could not be proved beyond doubt. The efforts are still continuing. The establishment of mini cement plants in rural areas will definitely go a long way in lowering the cost of housing in villages.

With regard to construction technology, the following three developments were carried out :-

(1) A new kind of wall design was developed which consist of kachcha bricks and baked brick in an interlocking arrangement. The details have been shown in the drawing no. 1. The wall thickness was kept at 13½", 50% of which was pucca bricks and 50% kuchcha bricks. No special shape of bricks was designed and interlocking system could be built up from the usually available bricks. Thus the superstructure has the following advantages :-

(a) The cost of 13½" thick wall is equivalent to 9" pucca wall.
(b) The heat load is reduced.
(c) Stability of the house is improved.

These walls were tested during two rainy seasons by keeping them standing in rains without any roofing. The interlocking system was found to be completely stable. Many times, kuchcha bricks at the house site are not available easily and they have to be transported from the brick kiln which add to the cost. After a review of the work, the kuchcha bricks were replaced by filling of mud mortar in between pucca bricks. Fig. 1A. This type of walls also were tested in open in the rainy season and were found to be stable. Cost reduction was about 20% than a 9" pucca brick walls. In the design, the pucca brick componant is 6 3/4" thickness only.

(2) Roofing - The roofing system developed was based on trapezium RCC beams; the design details are given in Fig. nos. 2 and 3. These beams could either be pre-cast on the site or could be supplied from a rural centre. The following construction details were used. The beams were placed 12" apart. The larger area of trapezium was on lower side. A 9" brick was inserted on the width side between these beams by breaking lower corner. This gives the lower side just like R.B. Slab roofing. On the top cement concrete was filled up and roofing was complete. The advantages of this roofing were :-

(1) No centering required to cast the roof,
(2) Heat load was reduced,
(3) There is no need for the villager to reduce or degrade the specifications. It gave the same strength as R.C.C. roof. Thus stability was ensured,
(4) The cost was reduced to about 80% of the standard R.B. slab roofing.

A major advantage of this roofing was that even if some crack appeared due to sinking of walls, the roof can be repaired easily by taking the portion apart which is not possible in the R.B. slab roofing.

In case the villager wants to remodel the house the roof can be dismantled and practically all the material can be reused except the mortar. Such kind of flexibility is desired by the villager and it was available to him when he was using wood timber roofing. About 50 houses were built according to this design and the roofs have not shown any deterioration even after 10 years.

A review of this system was made and it was decided to place these beams 18" apart. In place of filling the gap by brick, ferro cement slab of 1" thick was put on the lower side and another simultaneous plate of 2" thickness be placed on the upper side. There was thus a space left between these two blocks which is helpful in saving heat load and further lowering the own load of the roof. The cost of this kind of roofing was reduced to 70% of the standard roof. This suggestion was made by Dr. S.P. Jain, an Associate of the A.T.D.A.

(3) Flooring - Besides stability, another essential requirement of a floor is the imperviousness or very low water absorbing capacity. Both these qualities, the imperviousness and stability could be achieved when the flooring is laid down in 2 layer i.e. a lower layer of 1:6:12 cement concrete bed of atleast 4" thick and over it a second layer of atleast 1" thick of 1:4:8 cement concrete. But this is never followed in rural areas. Many times the broken baked bricks are packed with some lime and ash mixture or with a weak cement mortar and a sort of plaster is done on the upper side. Such floorings do not last long. No economy was found possible in the standard type of cement flooring, so in place of cement concrete flooring a new kind of red clay flooring was developed.

The red clay tile moulded from the same clay from which the baked bricks are manufactured was developed. The size of the tile was 8"x8"x2". They were baked in the same kiln alongwith the standard bricks. After baking the tiles were given a coating of neat cement of 1 mm thick and then they were cured in water tank for about 3 weeks. By using the

white cement and colouring oxides many good patterns just like mosaic flooring were produced.

The flooring was laid in 2 ways - broken bricks were spread on the floor and compacted. Over this compact surface, a thin surface of sand was given and tiles were laid dry. The joints were pointed by cement-sand mortar. (2) Over this compact bed, tiles were laid with mortar and every joint filled with cement and sand mortar. The cost of this flooring was about 60% of the standard flooring and about 5%-10% lower than the usual unstable cement flooring generally made in the village houses. This flooring was utilised in the pilot pottery factory and in a number of houses and the surface created of the tiles was found standing even after 5 years' use and the floor have a neat and clean look after proper cleaning. The advantage of this sort of flooring is that it has got a flexibility and can be repaired easily and the material can be re-utilised when any remodelling or reconstruction of the house is desired.

The extension work of all these techniques was to be organized through the pilot project of the mini-cement plant established at Mohanlalganj by P.R.A.I. But as the mini-cement project faced many teething troubles and ultimately was closed down, the extension was not taken up.

The A.T.D.A. has taken steps to re-establish the mini-cement project after seeking technical advice and guidance from German Government. As soon as the project is established and worked, the A.T.D.A. proposes to take up extension work of the above building technology alongwith development of village brick kiln.

...

B-35

79.12.03