ABSTRACT
The provision of low-cost housing is a continuous struggle for governments, as well as, for the individuals. Everyone is seeking the 'best' low-cost housing solution. In the past many attempts were undertaken to address this issue. One can find numerous examples of realized low-cost housing projects worldwide. However, the ideas and projects that were not taken forward and materialized are a multitude of that. It is of interest to analyze the existing low-cost housing and to draw lessons from them for the future. Is it possible to formulate a general set of requirements that a successful low-cost house should satisfy?

Eindhoven University of Technology is involved in the design and development of the housing sector in which, low-cost housing is an important part. Students of the University are developing models and interesting solutions. The paper will present an overview of low-cost housing building techniques and materials, lessons learnt, research results so far and ongoing research.

Keywords:
Low-Cost, Housing, Methods, Materials, Developing Countries

Contribution:
The contribution to the CIB 2007 congress ‘Construction for development’ is to inform and to give an overview of the research results so far and ongoing research on low-cost housing building components, in particular for developing countries.
1. INTRODUCTION

All over the world there is a shortage of decent low income housing. It is useful to distinguish low-cost housing and low-income housing. The first is housing built at low-cost, while the second is housing not necessarily built at low-cost.

In the latter case a concept has been developed, in which the users are able to pay for that housing. This affordability can be created by subsidizing the cost of housing (object subsidy) or of the users (subject subsidy). This can result in the ownership of the house, after a number of years, depending on the finance concept / agreement.

Apart from financial measures, the actual cost of housing can also be reduced by the use of low-cost materials, simple construction methods, repetition, smart designs (sharing walls e.g.) compact construction, not forgetting the option of self-help building, and other methods of financing.

Although all these ideas have been applied already, the housing shortage worldwide has not been solved yet. Of course, when looking at a local level, the causes may differ. For example, in the Netherlands, where money is available, the causes for the shortage are more qualitative (e.g. fewer rooms, low quality of the location or low comfort of housing). The causes for LDC’s may be:

- lack of sufficient middle-income housing (therefore occupation of low income housing);
- changing building bylaws causing low-cost housing to be below standard (e.g. energy inefficiency, although accepted by the users);
- lack of building capacity;
- lack of areas suitable for housing, and
- project developers whose aim is maximising profit. Therefore, shift occurs to the construction of high-cost housing.

This is a continuous struggle for the Dutch government in providing decent housing for the lower income groups.

2. CAUSES & SOLUTIONS FOR LOW-COST HOUSING IN LDC’s

Some of the causes described above are also applicable for developing countries. A basic problem is the limited finances set aside for housing and subsidising. In my view housing for low income groups have to be built at low-cost, including their surrounding area and required infrastructure (e.g. access roads, power, sewerage, water, etc). This should be organized in such a way that both costs of construction and exploitation should be covered by the contributions of the users/inhabitants. These costs can be lowered as follows:
- Smart financing methods – e.g. debt repayment over a longer period at a reasonable interest rate;
- The (effort) input of the inhabitants during the exploitation period for regular maintenance of the area;
- A financial contribution of the government, due to savings, when not responsible for the costs of maintaining the area;
- To build up the area in consecutive phases, without affecting the (capital) investments which have been already done. Caminos and Goethert (1978) have made calculations with respect to that;
- Reduction of the building costs by applying simpler construction methods, cheaper building materials and components.

This paper will elaborate on the reduction of these building costs and improving of the building materials for housing.

3. RESEARCH INTO LOW-COST HOUSING CONSTRUCTION

When drafting a research program, for low-cost housing from scratch, various considerations are of importance. The best would be, theoretically, the design of a universal low-cost house. However, this seems to be unlikely due to the differences among the following:

a) availability of local materials;
b) applicable building regulations;
c) building traditions;
d) climate;
e) patents for technologies (e.g. cast earth);
f) difference in culture;
g) availability of land and title deeds.

From a technical point of view building components can be investigated on a global scale. Most of the results will be universally applicable. Technically, a housing unit consists basically of the foundation, floor, walls, roof, sanitary units and items such as doors, windows, etc. When considering the construction costs of the superstructure, walls turn out to be the most expensive (19%) , followed by roofs (15%) of the total costs of the building elements (Erkelens, 1983).

Based on this fact, research should be focused on roofs and walls first. This is aligned with the perspective of the user, as he basically needs a roof for protection against rain, sun, etc; and walls for protection against coldness, heat, thieves, etc.

For years, Eindhoven University of Technology (TU/e) has carried out research, into low-cost housing construction. In some cases, it was developed in close cooperation with the former Housing Research and Development Unit (HRDU) of the University of Nairobi, the Delft University
of Technology (TUDelft) and the Instituto Urban y Region (IIUR) of the Universidad Nacional San Antonio de Abad Cusco (UNSAAC). The author was involved in this research.

It is known that the introduction of a completely new technology can destabilize existing systems and traditions. But, as most of the research is done in close cooperation with developing countries, the chance of inappropriate solutions is limited. This paper will present a brief overview of research results and ongoing research into roofing and walls.

4. RESEARCH INTO ROOFING

The HRDU carried out roofing experiments on the combination of papyrus polythene roofing. The idea was to simultaneously save on local materials and make it watertight. The structure was exposed to the equatorial sunlight for a number of years and the results were not unsuccessful. However the cultural acceptance of this combination of materials was limited, so it never left the laboratory. (See fig. 4.1).

b. The Nairobi University developed a 1.25m by 1 m roofing sheet consisting of a cement mortar and layers of sisal cement fibres.

![Fig. 4.1 Papyrus polythene roofing](image)

![Fig. 4.2 Sheets experiments](image)

The production process is very simple. The base plate is a corrugated mould. A square meter roofing sheet is prepared (mortar - fibres- mortar) on a flat plate, and the contents are moved into the base plate. After some hardening, the plate is lifted and placed in a curing area. Although promising, after some years at some spots the sheets started to leak due to cracks. The leakages were mended with some asphalt. The fibres were decaying. The production of these sheets has been stopped in many countries. It is believed that an improved fibre may increase chances for a restart. (See also fig. 4.2; Teerlink, 1980).

c. The roofing tiles as developed by Parry were more successful. The production process was simple: a mould for one tile has to be filled
with mortar, a concrete mixture. Vibration and curing was the most important aspect of this technique. Although suitable for self-help techniques, it requires discipline and understanding as how to make the right mixture and do the curing. (ITDG 1996).

d. The TU/e is now involved in the development of an improved roofing system for Tanzanian hospitals. Because of scarcity of energy, the existing roofing systems will be ‘opened’ up and provided with light openings. Together with the provision of more light, the ventilation shall be improved too, Meanwhile optimizing the amount of materials. (See fig. 4.3; Kreunen, 2007).

Fig. 4.3 Roofing light tests (Kreunen)

5. RESEARCH INTO WALL CONSTRUCTIONS

a. Already in the seventies, the TU/e became involved in the development of building blocks. Sonke (1975) developed a block with burls (negative and positive ones) as the Lego system. A small unit has been erected at the TU/e test site and it is still exists. In practice this turned out to be just ‘academic’ as (the African) loam has equal bonding capacities as the burls (fig. 5.1).
Also the construction process had to be changed as the construction with these types of mortar-less blocks requires a perfectly flat foundation, together with a precise measuring system for the walls themselves in order to remain in 'plumb' of a connection.

b. The Undugu Society of Kenya was confronted with fires in the 80's, in a squatter area in Nairobi. People wanted to reconstruct the area and to improve the housing quality. Traditionally low-cost housing is made of mud and wattle and a roof of corrugated iron sheets. It was decided now to apply a cement plaster layer on the outside of the mud and wattle walls. It took some time to find an experienced plasterer to do the craftsmanship. The result is astonishing as it gives the impression of ‘organic’ surfaces made of concrete (see fig. 5.2).

c. Another experiment was the Katangi experimental site of the Undugu Society of Kenya (Teerlink, 1979). Adobe bricks were put on the top of each other, without mud mortar in the joints, but with sisal fibres placed from inside to outside. These fibres were embedded in a cement sand plaster layer both in and outside (fig. 5.3). Experiments at the University of Nairobi showed that this type of construction improves the earthquake resistance, making the wall foundation a monolithic structure. However, after a decennium it was discovered the sisal fibres were decomposing just at the range between the plaster layer and the blocks. The use of a better fibre type should improve the performance of this type of wall. (Teerlink, 1979).

d. Cooperation between TU/D, TU/e and IIUR (Peru) led to a simple improvement of the earthquake resistance of existing adobe walls. The basic idea was to position a wire mesh net at an external wall with nails, hammered into the blocks. A plaster layer put on top of this mesh ensures, after hardening, that the wall behaves as a monolithic structure. This was proved during tests executed at UNSAAC. As this is a simple,
low-cost measure, this has been successfully applied at more locations (fig. 5.4; Kok, 1996).

Fig. 5.4 Wire mesh reinforcement
Fig. 5.5 Brepak press

The following research is the interesting development of the Brepak block press (Webb, 1988). The block making press has been developed as an excellent improvement of the Cinfra-ram and other presses, existing all over the world. The press consists of a manually operated pressure lever and a manually operated hydraulic mechanism. The produced blocks have a very smooth surface and a higher compressive strength, when compared with those from the older presses. An advantage is a finishing at lower cost. The press has been tested in many locations of the world and also the optimum type of soil mixtures and moisture contents were investigated. “Six people are needed for an efficient production. Two people to dig, two to prepare the mix by hand and two to operate the machine. Producing up to 300 high quality blocks per day” (fig. 5.6).

The prefabrication of concrete walls was tested in Kenya with mixed success. The reinforced precast walls and other concrete elements were cast on site. The problems were the smooth erection of a precasting yard, the timber moulding and the production itself (requiring continuous supervision) and the political climate. Because of the latter any further developments were stopped, as the former president disliked this method. The quality appeared to be low: cracks and noise problems were found. Nevertheless, successful cases of such a system were reported from Costa Rica. When studying this in more detail, the control and management is in
the hands of more experienced contractors and the production takes place in a fixed yard. (See figures 5.6 and 5.7).

g. In the period 1980-1990 new construction methods with adobe blocks and canes were developed, improving the earthquake resistance in Cusco. First, the ring beam was manufactured either from concrete or timber filled with loam. The canes were placed vertically in this base and inserted in the prefabricated holes of the adobe blocks during construction of the wall. The sticks were taken up in the following ring beam.
A different development (more earthquake resistant) is the use of *quincha* (cane) on both sides of a timber framework. The finishing can be a plaster layer of mud or gypsum. This structure is flexible and also heat insulating because of the cavity that is consequently created.

h. Building with earth is already very well known. It may be interesting to develop a system in which the earth can be used comparable to pouring concrete. For stabilization, the earth has to be mixed with a stabilizer, such as calcined gypsum (up to 15%). But this hardens too fast (within 30 minutes).

In USA a method of casting earth already exists. However, you have to follow a course, to buy a license and to purchase the additives for the earth. Cast earth has many advantages, and that is why the TU/e has an interest in this technique. The basic problem is the production of a local additive which retards hardening of the mixture of earth and gypsum.

The advantages of cast earth are the higher quality, higher production speed, a more monolithic structure, which is stronger, a smoother surface and a nice texture. Tests have shown that certain locally available products can be used for retardation (Vroomen, 2007).

6. CONCLUSIONS

This paper historically reviewed the research developments of TU/e, both in walls and roofing of low-cost housing in developing countries. Although considerable progress has been made, it is still necessary to put emphasis on such research and its proliferation and/or implementation also in LDC’s.
7. REFERENCES

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