THE USE OF EARTH AS AN APPROPRIATE BUILDING MATERIAL IN BRAZILIAN LOW-COST HOUSING

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ABSTRACT

This research is related to the possibility of using local soil as a building material in order to reduce costs concerning the construction of low-cost houses in Curitiba, Brazil. The main purpose is to find an effective solution for the huge Brazilian housing deficit of approximately 5 million housing units, mainly due to an accelerated population growth in urban centers. In this paper, an evaluation was made concerning a possible substitution of part of the walls (average masonry) with earth blocks in two different low-cost habitation sets for low-income people. The analyzed aspects were: cost reduction and the required energy amount for manufacturing the building materials.

KEYWORDS

Earth techniques, low-cost housing, appropriate technologies, soil, adobe, energy consumption.

INTRODUCTION

The idea of building low-cost houses with earth or soil (it means the same) in Brazil could be an interesting strategy to diminish the huge deficit for new dwellings, which, depending on the method of analysis, varies between 5 and 12 million housing units (6,656,526 in 2000, according to new data of the Fundação João Pinheiro, 2002). Local soil has been used as building material for more than 9000 years and around half of the low-income population in developing countries live in earth constructions (Minke, 1997). In Brazil, however, such constructions are commonly associated to the spread of diseases such as the Chagas infection (Tripanosoma cruzi), due to
precarious and improvised building techniques. This has as a consequence a widespread prejudice against earth constructions in Brazil.

Considering the importance of using appropriate technologies in Brazilian low-cost housing projects, earth techniques prove to be adequate, concerning several aspects of such technologies (Riedijk, 1979):

1. Require low investment;
2. A simple level of organization is needed;
3. Are adequate to local, sociocultural features;
4. Low cost-intensive, regarding the use of natural resources;
5. Low cost-intensive, regarding the final product;
6. Provide decentralization and facilitate self-help housing.

Also, local soil, which is normally obtained when preparing the building’s foundation, can be directly used in the building itself. Thus, this important feature of earth techniques is related to sustainable development and to environmentally sound constructions.

Another feature of earth materials is their versatility or the possibility of making thick or thin walls to improve indoor thermal conditions. Thick walls have been used in regions with greater temperature amplitudes such as hot-dry climates, where the heat, absorbed by the external walls during the day can be stored in these walls and, as the temperature drops at night, can then be lead to the interior. In hot-humid regions where the main bioclimatic strategy is ventilation, normally thin walls are used.

In this paper, two main aspects of building with local soil have been analyzed: first, an assessment of the possibility of substituting part of the walls in two examples of low-cost housing units with earth blocks, considering cost reduction; and, second, the required energy amount for manufacturing the building materials. This second aspect is related to the lesser amount of energy required to build with earth and to manufacture earth building materials.

**LOCAL EARTH AS AN APPROPRIATE BUILDING MATERIAL**

The main purpose of appropriate technologies is to promote an autonomy of the community, with local production according to local needs and, by doing so, to improve traditional techniques and local knowledge. Schematically, what is to be considered as an appropriate technology should follow the equation:
Traditional earth techniques have been developed and implemented by local communities and constitute part of the so-called vernacular architecture. The following diagram shows the different earth construction methods (Figure 1).

Regarding energy use, earth techniques require a much lesser energy amount than burned or fired clay do to produce bricks and tiles, which need about 850-1000°C in the kilns. Such kilns can be one of two types: intermittent and continuous; and the average energy consumption in those kilns is about 12000MJ/1000bricks and 3000MJ/1000bricks, respectively, depending on the kind of kiln used (clamp, scove and so on) (Stulz & Mukerji, 1993). According to Minke (1997), the use of soil requires about 1% from the total energy amount needed to manufacture bricks. Also, it can be used again (reusability), when recycling demolished buildings, and as it is a local building material, there are no extra costs and energy consumption necessary for transportation.

![Diagram of various earth construction methods](image)

**Figure 1: Various Earth Construction Methods (Stulz & Mukerji, 1993)**

Other advantages of using local soil as a building material are (Minke, 1997; Stulz & Mukerji, 1993):

1. Availability in most regions;
2. Low-cost;
3. Easy workability;
4. Suitability as construction material for most parts of the building;
5. Fire resistance;
6. Better control of indoor air moisture content: measurements conducted along 5 years in an earth building in Kassel, Germany, showed an almost constant relative humidity of 50% with a slight swing of 5%;
7. The already mentioned capacity of soil constructions to store heat (high thermal capacity and low thermal conductivity and porosity);

Nevertheless, earth constructions have some disadvantages:

1. Lack of standards: the soil must be known beforehand and carefully analyzed;
2. Excessive water absorption may lead to shrinkage and cause cracks: although the use of stabilizers and compaction could reduce or exclude water absorption and reinforce the soil with fibrous material (Stulz & Mukerji, 1993);
3. Earth elements must be protected against rain and water;
4. Earth constructions show low resistance to abrasion and impacts: newest research shows that the addition of 1% biomass to adobe could improve resistance to compression and that, by 7.7%, this resistance can be similar to that of average hollow ceramic bricks, traditionally used in Brazil (Faria & Espíndola, 2003).

POTENTIAL USE OF EARTH TECHNIQUES IN THE BRAZILIAN LOW-COST HOUSING SECTOR

The first attempts to rationalize Brazilian civil construction occurred in the 70s, with the town planning of Brasilia and with large-scale low-cost housing projects, which had similarities to European post-war mass housing projects regarding the use of mechanization and industrial manufacturing of building elements. In the 80s, due to a severe economic crisis, such level of industrialization was abandoned and new forms of small-scale rationalization techniques were developed.

Considering a basic characteristic of Brazilian civil construction sector, which is to use unqualified, unemployed personnel in the building process, applying appropriate technologies in low-cost housing projects could be beneficial, considering that such technologies are easy to handle and appropriate to self-help initiatives. One main disadvantage is related to the fact that usually a lower scale of production is involved. However, regarding the huge Brazilian deficit for new housing units, simple technologies, which can be easily assimilated by the community, could have a learning effect.

There are two possibilities for the construction sector: to maintain the present level of technology and rationalize the building process or to industrialize the civil construction sector (Bruna, 1983). The first solution applies mainly to the provision of low-cost housing for the poor, where self-housing initiatives may take place.

Considering the Brazilian low-cost housing sector, some of its main characteristics must be stressed:
1. The sector is responsible for job generation of unemployed people;
2. There are financial difficulties for new low-cost housing projects;
3. There is a huge demand for new and adequate housing units;
4. Massive low-cost housing projects with a broad application would not take into account the great cultural, socioeconomic and climatic diversities, which take place within the Brazilian territory.

From these characteristics, it is possible to devise the following priorities concerning the planning of new low-cost housing projects:

1. Need of a certain degree of rationalization of the building process;
2. Need of a better adequacy of the housing process to the local traditions;
3. Self-help initiatives should be regarded as a means of building new homes, whereas contributing to the improvement of building skills and abilities of the population.

**Earth techniques in Brazil**

During the colonization of Brazil, local soil was largely used as a building material (through the use of daubed earth and rammed earth techniques: see Figure 1), because of the simplicity of these techniques and due to the difficulties related to the shipping of building materials to the new territory. Earth techniques were then applied mainly in regions where stone materials were unavailable. Later, such techniques were substituted by burned ceramic bricks up to the point where they became obsolete and were regarded as provisional. The aspect of being “provisional” lead to the general disregard of earth techniques as a housing solution and to a widespread prejudice against earth constructions in Brazil (Santos, 2002). Today, considering the mentioned Brazilian low-cost housing deficit and the need of promoting sustainable development in all sectors, especially in the civil construction sector, which represented 14,5% of the Brazilian GNP in 1999 (John, 2000), earth techniques may be considered again as an interesting solution.

**THE USE OF EARTH IN LOW-COST HOUSING UNITS**

According to the Fundação João Pinheiro (2002), the need for new housing units is greater in the Southeast and in part of the Northeast regions of Brazil. In the State of Paraná (Figure 2), this deficit lies in second range (250.000 – 500.000 housing units) and in absolute terms comprised 260.000 housing units in 2000, mainly in urban areas (89%). Only in the urban area of Curitiba, there was a need of 70.489 new homes. Considering this last deficit, two low-cost housing projects, already implemented by the local public housing company (Companhia de Habitação Popular de Curitiba – COHAB-CT), were evaluated regarding the partial substitution of existent walls, built with average ceramic bricks, with earth blocks (adobe).
Two different housing types were considered for this analysis:

1. Two-storied apartment blocks (Figures 3 and 4) with a built area of 36.45m² for each housing unit, built with conventional ceramic hollow bricks;
2. Single storied houses (Figures 5 and 6) with a built area of 28.65m², also using ceramic hollow bricks.
FIGURE 4: APARTMENT BLOCKS (FLOOR PLAN)

FIGURE 5: SINGLE STORYED HOUSES (FRONT VIEW)

FIGURE 6: SINGLE STORYED HOUSES (FLOOR PLAN)
The analysis consisted of verifying the possibility of substituting conventional masonry with earth elements, provided that those walls did not have openings and do not constitute wet walls, such as washrooms, kitchens or bathrooms. Also, the structural features of the buildings were evaluated, by identifying which walls have structural characteristics.

The sum of all walls in the apartment blocks yielded 63,48 m² for housing units on the first floor and 69,46 m² on the second floor. Concerning these areas, built with conventional masonry, it was concluded that 8,71 m² and 9,35 m², for first and second floor, respectively, could be substituted by adobe bricks. The volume of soil needed to manufacture such earth blocks was then calculated for a wall thickness of 25 cm. The resulting volume of soil for first and second floor housing units was 2,17 m³ and 2,33 m³, respectively. Table 1 shows these quantities.

<table>
<thead>
<tr>
<th>Apartment blocks</th>
<th>Masonry (ceramic bricks)</th>
<th>Walls, which could be substituted by earth blocks</th>
<th>Percentage of walls, which could be substituted by earth blocks</th>
<th>Resulting volume of soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>First floor</td>
<td>63,48 m²</td>
<td>8,71 m²</td>
<td>13,72%</td>
<td>2,17 m³</td>
</tr>
<tr>
<td>Second floor</td>
<td>69,46 m²</td>
<td>9,35 m²</td>
<td>13,46%</td>
<td>2,33 m³</td>
</tr>
</tbody>
</table>

The same procedure was used for the single storied houses.

Next step was to quantify the soil removal for building the apartment blocks. The main removal was related to its foundations. Footings and corresponding foundation walls were used, generating 0,12 m³ of local soil, appropriate to be used as earth material, for each footing. For the total of 36,5 footings (one footing was common to both units on each floor), 4,38 m² of local soil could be considered as suitable for substitution, which is almost what is needed for both units in the first and second floor (4,50 m²).

Regarding the single storied houses, the percentage of walls which could be substituted by earth blocks was 10,37%, yielding 2,28 m³ of soil.

**Energy Consumption**

Building materials demand different energy amounts, according to the level of industrialization and to the process used to convert natural resources into building elements. This energy consumption begins with the extraction of raw materials, goes through its transportation to the building site and comprehends the industrial process as well, which is generally centralized. The trend towards a progressive disregard of using local materials in favor of industrialized ones, for technical or financial reasons, leads to a substantial increase in energy consumption and waste emission. The energy content of the main materials that constitute a building system is another parameter that could be taken into account when planning for the low-cost housing sector. According to Mascaró & Mascaró (1992), the energy consumption for each building step is distributed according to Table 2.
TABLE 2: ENERGY DEMAND FOR EACH BUILDING STEP

<table>
<thead>
<tr>
<th>Step</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabrication of building materials</td>
<td>96.41%</td>
</tr>
<tr>
<td>Transportation</td>
<td>1.38%</td>
</tr>
<tr>
<td>Foundation</td>
<td>0.57%</td>
</tr>
<tr>
<td>Construction</td>
<td>1.24%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

The energy amount needed to manufacture ceramic materials in Brazil, compared to their percentage of participation in the total costs of an average low-cost house was surveyed by Guimarães (1985, Table 3).

TABLE 3: CERAMIC MATERIALS: ENERGY CONSUMPTION AND PARTICIPATION IN THE TOTAL COSTS OF AN AVERAGE LOW-COST HOUSE (GUIMARÃES, 1985)

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage in energy consumption</th>
<th>Percentage in the total costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic tiles</td>
<td>11.0%</td>
<td>5.0%</td>
</tr>
<tr>
<td>Hollow bricks</td>
<td>19.5%</td>
<td>2.5%</td>
</tr>
<tr>
<td><strong>Azulejos and Ceramic elements</strong></td>
<td><strong>32%</strong></td>
<td><strong>8.0%</strong></td>
</tr>
</tbody>
</table>

The use of earth materials could mean a substantial reduction of the energy consumption (in that case, only man-power would be required: manual presses can be easily used to create adobe blocks) without necessarily increasing the final costs. Whereas the participation of masonry in the final costs of an average low-cost house is low (not more than 10%), its percentage regarding energy consumption for manufacturing this building material reaches 57%.
FIGURE 7. ENERGY CONSUMPTION FOR DIFFERENT BUILDING ELEMENTS (GUIMARÃES, 1985)

FINAL REMARKS

Earth constructions can be a solution to Brazilian great low-cost housing deficit. These technologies can be easily reproduced by the local population and could regain the character of being part of the local culture. In this paper, a brief description of these building techniques was made and an evaluation of a possible use of earth blocks in low-cost housing units was performed. These results were the starting point for other research initiatives, which now take place at the Faculdade de Arquitetura e Urbanismo in the Centro Universitário Positivo, in the Laboratório de pesquisa com terra (Figures 8-10).
REFERENCES


