RAW EARTH CONSTRUCTION IN PATAGONIA

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ABSTRACT

The research work and field tests described in this article were carried out at the Material and Component Testing Laboratory of the Polytechnic of Turin and in the territory of Junin de Los Andes in the north of Patagonia, Argentina. The use of stabilised raw earth as a building material is promising in that it may foster self-help construction activities by the Mapuche natives that live in the area. The results of field and laboratory tests are described, and an account of site activities during the construction of a prototype building is provided.

KEYWORDS

Raw earth, stabilisation, self-help construction, low cost.

INTRODUCTION

In the Mapuche reserves in the area of Junin de Los Andes (Region of Neuquén – Argentinean Patagonia) and even in some parts of this small town there is a severe shortage of decent housing. Many homes are poorly constructed and precarious, and this has detrimental effects on hygienic conditions and people’s health (Figure 1). The building programs that the public administration has tried to put in place in recent years failed to meet the needs of the population and, in most cases, people cannot afford the investment required (Figure 2): hence the need to explore possible alternative solutions.

Among the materials available locally, raw earth, a typical low-cost material, has been considered for use as a building material for self-help construction. Widely used in the past, with the advent of modern industrial products - such as steel and concrete - earth was almost totally put aside. In recent years, however, the coming to the fore of concepts such as sustainability, ecology and ecocompatibility has awakened fresh interest in the potential of this material and its use in building applications, an interest which is not limited to the Developing Countries.
Raw earth, in fact, is cheap, on account of it being available virtually anywhere; moreover, it requires reduced quantities of energy both for the production of building components and for maintenance and recycling purposes. Albeit based on traditional methods, present-day utilisation techniques make it possible to overcome the problems associated with this material, such as its behaviour in wet climates, maintainability and durability.

Based on these premises, this study has defined a proposal for low-cost housing, to be produced through self-help and by adopting technological measures designed to ensure quality and durability. The testing campaign focused on the use of compressed and stabilised raw earth blocks produced by means of a simple hand press, modified at the Material and Component Testing Laboratory of the School of Architecture of the Polytechnic of Turin to make interlocking blocks.

**Figure 1. Raw earth house in the Chiquilihuin reserve (Patagonia – Argentina)**

**Figure 2. Houses erected by the city administration of Junin de los Andes (Patagonia–Argentina)**

**THE MISSION TO PATAGONIA**

After examining the climatic conditions of the territory concerned, a number of preliminary investigations were conducted into the thermal-physical behaviour of different types of wall made of raw earth, either alone or combined with other materials. The materials’ heat transmittance, \( U \) [W/m\(^2\)°C], delayed heat transmission, \( \Phi \) [h], front thermal capacity, \( C_F \) [KJ/m\(^2\)°C] and attenuation factor, \( f_a \) [-] were compared, as listed in Table 1.

During the stay in the area, a suitable soil for the blocks was selected through field tests (Figures 3, 4) and through the production of a limited quantity of sample blocks using different soils and stabilised with different cement proportions. After the curing period, the different types of block were tested directly to assess their quality and feasibility (Figures 5, 6).
TABLE 1. COMPARISON BETWEEN THE DIFFERENT WALL TYPES

<table>
<thead>
<tr>
<th></th>
<th>Concrete blocks</th>
<th>Hollow bricks</th>
<th>Solid bricks (not insulated)</th>
<th>Machimbre earth blocks</th>
<th>Stabilised earth blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIMENSIONS</td>
<td>cm 40x20x20</td>
<td>cm 33x18x18</td>
<td>cm 30x6x15</td>
<td>cm 28x9.5x14</td>
<td></td>
</tr>
<tr>
<td>COST ANALYSIS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost [S/m²] (*)</td>
<td>12.94</td>
<td>14.97</td>
<td>17.42</td>
<td>19.32 (**))</td>
<td>8.72 (***)</td>
</tr>
<tr>
<td>THERMOPHYSICAL ANALYSES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmittance [W/m²°C]</td>
<td>2.116</td>
<td>1.792</td>
<td>2.421</td>
<td>1.687</td>
<td>1.674</td>
</tr>
<tr>
<td>Front thermal capacity [KJ/m²°C]</td>
<td>131.9</td>
<td>207.6</td>
<td>253.0</td>
<td>53.0</td>
<td>197.1</td>
</tr>
<tr>
<td>Delayed heat transmission [h]</td>
<td>2.88</td>
<td>5.39</td>
<td>4.88</td>
<td>1.66</td>
<td>5.46</td>
</tr>
<tr>
<td>Attenuation factor [-]</td>
<td>0.85</td>
<td>0.63</td>
<td>0.65</td>
<td>0.93</td>
<td>0.63</td>
</tr>
</tbody>
</table>

(*) Costs referred to January 2001.
(**) Cost per m², determined from a quotation
(***) Cost per m², assuming the cost of earth is the same as that of sand.

Following a well tested procedure, after the preliminary field tests, a training course was organised locally on block production by means of a hand press, GEO 50 by AKterre (Figure 7). Though the blocks are characterised by regular dimensions and can be laid with ease by unskilled personnel, the innovative aspect of this proposal does not so much lie in the shape of...
the blocks as in the manufacturing process, which makes it possible to produce self-locking blocks with the same equipment as is normally used to make plain blocks.

![Image: Interlocking block produced with GEO 50 hand press]

**FIGURE 7. INTERLOCKING BLOCK PRODUCED WITH GEO 50 HAND PRESS**

**LABORATORY TESTS**

The earth sample deemed suitable was subjected to laboratory tests to determine with greater accuracy the compressive strength of the material and its behaviour in freezing temperatures. The tests were performed at the Material and Component Testing Laboratory of the D.I.N.S.E. Department of the School of Architecture of the Turin Polytechnic.

**Technical data of the earth used**

- Composition (Table 2)

<table>
<thead>
<tr>
<th>Particle size analysis</th>
<th>methylene blue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel</td>
<td>3.5%</td>
</tr>
<tr>
<td>Sand</td>
<td>83%</td>
</tr>
<tr>
<td>Limo</td>
<td>12%</td>
</tr>
<tr>
<td>Clay</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

\[ V_{B(0)} = 1.6 \text{ cm}^3/\text{g} \]
Diffactometric analysis (Figure 8)

![Diffactometric analysis graph](image)

**FIGURE 8. RESULTS OF DIFRACTOMETRIC ANALYSIS**

In view of the modest quantity of soil available, the tests were performed on cylindrical test pieces ($\varnothing = 60 \text{ mm}, H = 89 \text{ mm}$), compacted with the same force (2MPa) as is applied by the hand press used locally. The test pieces were made according to the proportions (Table 3) identified in Patagonia as ensuring the best composition for block production.

**TABLE 3. TEST PIECE COMPOSITION**

<table>
<thead>
<tr>
<th>Materials</th>
<th>Quantity (g)</th>
<th>Wet weight (g)</th>
<th>Dry weight (g)</th>
<th>Specific weight (kg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>350</td>
<td>439</td>
<td>386</td>
<td>1533</td>
</tr>
<tr>
<td>Cement</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N.B.: low specific weight is due to the light weight of the aggregates contained in soil of volcanic origin.

The next step consisted of assessing the effectiveness of a surface treatment obtained by applying cooked linseed oil. To provide a term of comparison, some test pieces (5 per type) were treated with a clear solution of low molecular weight syloxane.

**Water absorption**

This test was performed according to the modalities specified in standard UNI 8942-3:1986 *Brick products for masonry structures: testing methods*. First, the test piece is dried to constant weight, then it is placed in contact with 1 cm of water for 60 sec. Specific absorption is determined from the quantity of water in relation to the area in contact. Figure 9 shows the difference in specific absorption as a function of the protective treatment applied to the test pieces.
N.B.: the mean value was determined over the three most homogeneous values.

FIGURE 9. ABSORPTION AS A FUNCTION OF SURFACE TREATMENT APPLIED

**Imbibition**

This test was performed according to the modalities specified by the aforementioned UNI standard (8942). When it has been dried to constant weight, the test piece is immersed in water for 24 hours. Figure 10 illustrates the results obtained from the different types of treatment. Moreover, from the diagram it can be seen that absorption during the first 6 hours accounts for approx. 80% total absorption: this is a valuable tip to reduce field testing times.

**Frost test**

To make it easier to reproduce freezing-thawing cycle tests in the field, it was decided to adopt a testing method specified by an Italian standard previously used for brick acceptance tests. After 28 day curing in an environment where $T = 20^\circ C$ and R.H. = 50%, the tests pieces were subjected to a cycle that involved immersing the test pieces in water at $+35^\circ C$ for 3 hours and placing them in a refrigerator at $-10^\circ C$ for another 3 hours. This cycle was performed twenty times. All the test pieces passed the freezing-thawing test: at the end of the test their compressive strength was 70% the initial value. This was rated as satisfactory vis-à-vis the value specified by current standards on bricks (80% the value of initial strength). This result was confirmed in the climatic environment in which the prototype building was constructed. Test results are listed in Figure 11.
N.B.: the mean value was determined over the three most homogeneous values.

FIGURE 10. IMBIBITION AS A FUNCTION OF SURFACE TREATMENT APPLIED

N.B.: the mean value was determined over the three most homogeneous values.

FIGURE 11. COMPRESSIVE STRENGTH AS A FUNCTION OF SURFACE TREATMENT APPLIED

(a) In this test piece, compressive strength is higher thanks to the treatment with linseed oil, which has created a permanent coating that makes for improved strength.

Transferring the results to the field

At the end of the training course (Figures 12, 13, 14), a hands-on training construction site was set up to construct a small prototype building on the outskirts of Junin de Los Andes. Construction works got underway in January 2001 (Figure 15). Following this initial experience, numerous requests were received from the local population wanting to build their homes with the construction system using self-locking blocks, but the insufficient availability of buildable plots of land owned by the applicants and the lengthy bureaucratic procedures for the assignment of the grounds slowed down the activity.
In 2003, in the Mapuche community of Atreuco, the construction of a small community centre got underway: it is hoped that when bureaucratic difficulties are overcome, this construction system that meets the wishes of the local population can be extended to many other interventions.

**REFERENCES**


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