Compressed earth blocks (CEB) with no added cement

ENVIRONMENT

This article analyses the behaviour of compressed earth blocks (CEB) with no added cement, using various tests to do so. CEBs are an alternative wall building material offering significant economic and environmental advantages over traditional cement-based materials. This makes them a promising option for the construction industry.

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This research project studies an alternative wall-building material called compressed earth block (CEB) with no added cement. Two main advantages accrue from removing cement from the basic CEB mixture: firstly, an economic benefit, because the price of cement makes the cost of the block much higher, and secondly an environmental benefit due to the impact of the cement manufacturing process. CEBs have a lower environmental burden than bricks because they are not kiln fired, but the addition of cement as stabiliser forfeits some of this environmental advantage.

Generally, earth with a high clay content is considered unsuitable for making CEBs since clayey soil calls for more added cement than sandy soil to achieve acceptable strength. This is reflected in the IRAM (Argentinian Standardisation and Certification Institute) rules, which specify that up to 15% cement has to be added for making cement-stabilised earth blocks from clayey soils. This rules out a wide range of soils for making CEBs, unless there is the possibility of adding sand or, as a worse option, increasing the amount of cement. This in turn implies a higher economic and environmental cost.

The main input of this research project will be the possibility of harnessing the natural agglomeration quality of clay soils without the need of adding cement to the block. Rather than by adding cement, stabilisation of the block will be achieved by compaction, using methods that guarantee compliance with theoretical premises in the factory and on site. This chimes in with today’s ongoing concern for developing more sustainable construction materials.

This research was carried out by working with three types of clayey soils compacted at three different pressures, 4 kg/cm², 6 kg/cm² and 8 kg/cm². These three test specimens were chosen to demonstrate that the block’s compression strength increases in direct proportion to the plasticity of the earth, subjected in turn to a high compaction pressure.

Another aim of the research was to solve the material’s water sensitivity by waterproofing it with used vehicle oil.

Finally it was shown empirically that CEBs made from medium-
plasticity clayey-sand earth, duly compacted and waterproofed with used vehicle oil, produce a viable building block.

1. Description of the Project

This research project set out to study the behaviour of an alternative wall-building material (compacted earth block, or CEB, with no added cement). This block cuts out the kiln-firing stage in its manufacture, the stage with the highest environmental burden, not only because of the air emission of pollutants (thereby stoking up the greenhouse effect) but also because of the consumption of non renewable resources (timber from natural woodland and natural gas) in the production of the vast amounts of energy needed in the process. There is proven experience of the good behaviour of cement-stabilised compressed earth blocks; there has been no research, however, into the behaviour of blocks without added cement. Two main advantages accrue from removing cement from the basic CEB mixture: firstly, an economic benefit, because the price of cement makes the cost of the block much higher, and secondly an environmental benefit due to the impact of the cement manufacturing process.

2. Problems to be Solved

One of the main reasons for the environmental deterioration of the natural world in recent decades has been the overexploitation of natural resources (including fertile soil), air pollution and the pollution and exhaustion of hydrological resources, all caused by the hand of man. As a result ecosystems have been altered and human health has often been put at risk, with a concomitant and pronounced fall in quality of life in certain sectors.

The construction industry in particular has been an economic and social boon in terms of producing goods and services. On the downside, however, it has historically called for a vast input of raw materials and energy, leading in turn to the emission of large amounts of gaseous, liquid and solid emissions, all environmentally polluting.

Down the ages the various construction systems have been unable to replace bricks as a construction material, especially in Latin America. There are two main reasons for this, one economic and the other cultural: firstly, bricks are relatively cheap and secondly they are perceived as a high-status building material in comparison to adobe. Their manufacture calls for no sophisticated technology or skilled labour (Muller, M, 1997). These circumstances still hold true today because the external environmental and social costs of the production process are not being internalised by the industry.

Augenbroe (1998), for example, argues that it now behoves the construction sector to change its working methods, taking into account such factors as user satisfaction while also striving to use less energy and matter and therefore cut its environmental impact. This paradigm shift is shown in figure 1.
Figure 1. Sustainable construction calls for a new paradigm (Augenbroe, 1998).

An environmental evaluation of the construction sector requires a quantification and qualification of the resources consumed and emissions given out in the various process stages.

Some of the main factors in choosing environmentally-friendly building material are summed up below:

- Energy saving. The main manufacturing cost of the block involves only the cost of conveying the earth to the site, a routine procedure since earth is a material within easy reach of most building sites. Furthermore, if the earth comes from the excavation work on the site itself, two birds are killed with one stone, compounding the savings. Technically, moreover, it is a very advantageous material with great energy-saving potential in heating and cooling terms.

- Reclaiming of waste. This involves not only the use of waste from other industries but even the possibility of recycling the earth block itself at the end of its useful life.

- Clean technology. No contamination or noise, gaseous or thermal pollution of any type is produced during the block manufacturing process; the only wastage is offcuts, all of which is in turn recyclable later as aggregate or inert earth for making new blocks.

- Non toxicity. The material gives off no type of radiation or toxic product during its useful life.

- Durability. It is a long-lasting and easily maintained material; properly clad, it suffers no attacks from microorganisms.

- Lastly, the cheapness of the material will help to reduce homelessness, especially in Latin American countries, where about 135 million people lack any sort of decent housing; it is also conducive to more sustainable construction.

According to the criteria for environmental friendly selection of material as proposed by Fábregas (1998), compressed earth blocks with no added cement tick all the boxes.

**Historically, the construction sector has needed vast amounts of raw materials and energy, in turn provoking the release of huge amounts of pollutants into the air.**
3. Theoretical Framework

One of the outstanding properties of clay is its inter-particle cohesion. This cohesion is a function of attraction and repulsion between the particles, acting as electric charges with variable intensity depending on the distance between them or the interlaminar distance. With a low humidity content clays form a coherent solid with high densities (Fratelli, Graciela; 1993). The presence of water lessens this cohesion. The intrusion of water in the interlaminar space tends to separate the lamellas, causing swelling or degradation. When the amount of water between the lamellas increases they separate, reducing the forces of cohesion and increasing electrostatic repulsion (García Romero, Emilia; 2007). We therefore need to bring the particles closer together and avoid entry of water to maintain the natural cohesion of clays.

The compression-induced cohesion will reduce the block’s water absorption rate but it will not avoid the gradual degradation of the block’s surface layers, as an effect of direct contact, and this will allow water into the first interlaminar spaces. Waterproofing surface treatment can head off this effect and further stabilise the block’s behaviour. The research project called «Alternative weatherproofing techniques for traditional adobe walls», carried out for the Universidad Nacional de Tucumán (Argentina) by Irene C. Ferreyra, Stella M. Latina, Rafael Soria Nieto and Rafael F. Mellace, shows that surface oil treatment of unfired earth blocks (traditional adobe) will improve their water performance.

The complex behaviour of clays was analysed from the physical-mechanical point of view to assess the properties of interest to this research. The study of the Atterberg limits, liquid limit, plastic limit, plasticity index and plasticity chart give us important insights into the physical-mechanical behaviour of clays. «The relation between the liquid limit and the plasticity index gives a great deal of information on the grading, behaviour, nature and quality of the clay». (García Romero, Emilia; 2007).

4. Objectives and Purpose

4.1 General Objective

- Contribute towards the development of building-block manufacture technology that has a low economic and environmental cost, the blocks lending themselves to self-construction and/or small production units.

4.2 Specific Objectives

- Develop the manufacturing procedure of CEBs with no added cement, achieving good physical and mechanical qualities, with the lowest possible energy cost.
- Improve and upgrade the SIMVA RAM type press to obtain high compaction pressure and obtain figures on the intensity thereof.
- Record the research results in an operative CEB manufacturing handbook for the manufacturer of material of this type, with clear and precise instructions, with procedures and units designed for minimum onsite equipment.

4.3 Purpose

Encourage the use of CEB-type blocks in building work as a valid alternative, on the strength of its sustainable properties, with recommendable mechanical and physical behaviour, helping to solve the problem of high energy costs of currently used
5. Methodology

5.1 Substantive Hypothesis

It is possible to manufacture compressed earth blocks (CEBs) without cement stabilisation and obtain recommendable physical and mechanical behaviour, using medium-plasticity clayey type soil by applying high compaction pressure, taking into account the Proctor theory and waterproofing the block surface with used engine oil.

5.2 Working Hypothesis

If cement-stabilised compressed earth blocks are made by taking the following conditions into account, recommendable physical (water absorption) and mechanical (compression strength and water abrasion) behaviour will be obtained with clayey type soil, except for soils with a high content of organic matter (especially acid soils):

- Correct soil classification, ascertaining the type of clay in each one.
- Using clayey-type soil or sand with a medium-plasticity clay content (SC).
- Increasing the compaction pressure, at least to 8 kg/cm², to achieve an increase in the dry unit weight, in light of the optimum humidity and the energy to be applied, thereby obtaining greater particle cohesion (Proctor).
- Block-surface waterproofing with used engine oil.

The independent and dependent variables were established. Within the set of dependent variables, consideration was given to the physical and mechanical properties. As for the independent variables, the type of soil and compaction pressure were proposed.

5.3 Variable Chart

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Type of soil</th>
<th>Compaction pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variables</td>
<td>Physical properties</td>
<td>Water absorption</td>
</tr>
<tr>
<td></td>
<td>Mechanical properties</td>
<td>Compression strength</td>
</tr>
</tbody>
</table>

5.4 Design of the Procedures

- Three different types of soil were analysed and classified according to the following standards, by means of grading tests, liquid limit and plastic limit (12 tests).
- Proctor types tests were conducted on soil S1, with compression of 6 kg/cm² and 8 kg/cm²; soil S2, with compression of 4 kg/cm² and 8kg/cm², and soil S3, with 8 kg/cm² (20 tests).
- A total of 114 test pieces were made with the CBR press and small Proctor test mould with 10-centimetre diameter, from the three types of classified soil, compressed at different pressures (4, 6 and 8 kg/cm²) to carry out the compression, water absorption and abrasion tests.
Authors like Augenbroe argue that the construction industry is duty bound to change its working methods, taking into account such factors as user satisfaction, lower energy consumption and lower environmental impact.

6. Data Collection and Processing

6.1 Classification of soils

Soil type S1
- Well graded sand
- 10.13% passes No. 200 sieve (0.075 mm)
- Liquid limit = 33.10
- Plastic limit = 19.72
- Plasticity index = 33.1 - 19.72 = 13.38

Soil type SC – medium plasticity clayey sand

Soil type S2
- Well graded sand
- 21% passes No. 200 sieve (0.075 mm)
- Liquid limit = 33.10
- Plastic limit = 19.72
- Plasticity index = 26.3 - 18.82 = 7.48

Soil type SC – low plasticity clayey sand

Soil type S3
- Well graded sand
- 23.19% passes No. 200 sieve (0.075 mm)
- Liquid limit = 37.45
- Plastic limit = 21.64
- Plasticity index = 37.45 - 21.64 = 15.81

Soil type SC – medium plasticity clayey sand

6.2 Proctor Tests

Soil S1 Optimum humidity for compression of 8 kg/cm2 = 17.34%

Soil S2 Optimum humidity for compression of 8 kg/cm2 = 21.6%

Soil S3 Optimum humidity for compression of 8 kg/cm2 = 24.00%

6.3 Compression Tests

6.3.1 Compression tests of soil S1 test pieces

Table 1. Compression tests of soil S1 test pieces

| Compaction pressure 4 kg/cm² | Test pieces tested 6 (six) |
6.3.2 Compression tests of soil test pieces S2

Table 2. Compression tests of soil S2 test pieces.

<table>
<thead>
<tr>
<th>Compaction pressure (kg/cm²)</th>
<th>Test pieces tested (six)</th>
<th>Mean unit weight</th>
<th>Mean tension</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td></td>
<td>1.57</td>
<td>14.56</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>1.60</td>
<td>18.73</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>1.62</td>
<td>24.33</td>
</tr>
</tbody>
</table>

6.3.3 Compression tests of soil S3 test pieces

Table 3. Compression tests of soil S3 test pieces.

<table>
<thead>
<tr>
<th>Compaction pressure (kg/cm²)</th>
<th>Test pieces tested (six)</th>
<th>Mean unit weight</th>
<th>Mean tension</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td></td>
<td>1.614</td>
<td>43.93</td>
</tr>
</tbody>
</table>

This soil S3 shows a sharp increase in mean compression strength over soils S1 and S2, in comparison to which this soil has a higher plasticity.

An analysis of the figures set forth in the above paragraphs shows that there is a relation between the compression strength of the test pieces and the plasticity of the clays they were made from.

The basic hypothesis of this research work is that CEBs can be made without cement, obtaining recommendable physical and mechanical behaviour parameters

6.4 Water Absorption Tests

6.4.1 Water absorption tests on soil S1 test pieces
In principle a great time difference to start of breakdown is observed between the test piece with oil (mean time 1h 40 min) and without oil (0h 05 min); this difference is less in terms of rupture time, which is an average of 3h 20 min for the former and 1h 55 min for the latter.

Time to start of breakdown and rupture time are also seen to vary in direct relation to compaction pressure.

6.4.2 Water absorption tests on soil S2 test pieces

Table 5. Mean Absorption Times – Soil S2

<table>
<thead>
<tr>
<th>Compaction pressure (kg/cm²)</th>
<th>Average time to start of breakdown</th>
<th>Average time to rupture</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,00</td>
<td>0h 50min</td>
<td>1h 50min</td>
</tr>
<tr>
<td>6,00</td>
<td>2h 43min</td>
<td>6h 56min</td>
</tr>
<tr>
<td>8,00</td>
<td>3h 43min</td>
<td>8h 08min</td>
</tr>
<tr>
<td>Test piece 8 kg/cm² without oil</td>
<td>0h 05min</td>
<td>2h 00min</td>
</tr>
</tbody>
</table>

Soil S2 shows even greater differences between the readings than S1. Start of breakdown in the test piece with oil is seen to be an average of 2h 40 min, while without oil the time is only 5 min. Rupture time also shows a big difference: 6h 30 min for the former and 2h 00 min for the latter.

6.4.3 Water absorption tests on soil S3 test pieces

In the case of soil S3 only 8 kg/cm² test pieces were tested, in view of the fact that the previous tests had already produced sufficient figures for analysing water absorption in relation to compaction pressure.

Table 6. Mean Absorption Times – Soil S3

<table>
<thead>
<tr>
<th>8 kg/cm² test piece with oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test pieces</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>TP1</td>
</tr>
<tr>
<td>TP2</td>
</tr>
<tr>
<td>TP3</td>
</tr>
<tr>
<td>Mean time</td>
</tr>
</tbody>
</table>
6.5 Water Drop Abrasion Tests

6.5.1 Water abrasion tests on soil S1 test pieces

The oil-impregnated test piece lasts far longer than the test piece without oil before showing a dent (average 0h 52 min as compared with 0h 10 min). There is also a big difference in the depth of the dent, 1.35 mm average for the former and 4.65 mm for the latter.

### Table 7. Mean water abrasion time - Soil S1

<table>
<thead>
<tr>
<th>Test pieces</th>
<th>Start of dent</th>
<th>Dent at 1 hour (mm)</th>
<th>Without dent at 1h 30 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test pieces 4 kg/cm²</td>
<td>0h 19min</td>
<td>6,3</td>
<td>No</td>
</tr>
<tr>
<td>Test pieces 6 kg/cm²</td>
<td>0h 22min</td>
<td>5,33</td>
<td>No</td>
</tr>
<tr>
<td>Test pieces 8 kg/cm²</td>
<td>0h 52min</td>
<td>1,37</td>
<td>No</td>
</tr>
<tr>
<td>Test pieces 8 kg/cm² without oil</td>
<td>0h 10min</td>
<td>4,65</td>
<td>No</td>
</tr>
</tbody>
</table>

The oil-impregnated test piece lasts far longer than the test piece without oil before showing a dent (average 0h 52 min as compared with 0h 10 min). There is also a big difference in the depth of the dent, 1.35 mm average for the former and 4.65 mm for the latter.

6.5.2 Water abrasion tests on soil S2 test pieces

### Table 8. Mean water abrasion time - Soil type S2

<table>
<thead>
<tr>
<th>Test pieces</th>
<th>Start of breakdown</th>
<th>Rupture (15%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>0h 02min</td>
<td>0h 40min</td>
</tr>
</tbody>
</table>

The water-drop-test behaviour of these test pieces merits close attention. In principle we see that they put in the best performance, showing no dent in 90% of the cases, with a marked difference between those treated with oil and those not.

6.5.3 Water abrasion tests on soil S3 test pieces

In the case of soil S3 only 8 kg/cm² test pieces were tested in
view of the fact that the previous tests had already produced sufficient figures for analysing water abrasion in relation to compaction pressure.

### Table 9. Mean water abrasion time - Soil S3

<table>
<thead>
<tr>
<th>Test pieces</th>
<th>Start of dent</th>
<th>Dent at 1 hour (mm)</th>
<th>Without dent at 1h 30 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test pieces 8 kg/cm²</td>
<td>0h 20min</td>
<td>7,07</td>
<td>No</td>
</tr>
<tr>
<td>Test pieces 8 kg/cm² without oil</td>
<td>0h 4min</td>
<td>8,00</td>
<td>No</td>
</tr>
</tbody>
</table>

#### 6.5 Alcock’s Linear Shrinkage Test

#### Table 10. Linear shrinkage values

<table>
<thead>
<tr>
<th>Type of soil</th>
<th>Shrinkage (cm)</th>
<th>Total Length</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2</td>
<td>2,09</td>
<td>61</td>
<td>3,43</td>
</tr>
<tr>
<td>S1</td>
<td>2,47</td>
<td>61</td>
<td>4,05</td>
</tr>
<tr>
<td>S3</td>
<td>3,22</td>
<td>61</td>
<td>5,28</td>
</tr>
</tbody>
</table>

### 7. Data Processing and Analysis

The material worked with met the following conditions: two soil samples taken from excavations for building foundations and a third from a brick clay quarry.

Classification of the three types of earth resulted in three clayey sands: two of medium and a third of low plasticity. The importance of this figure lies in the fact that such earth is generally abundant. The most suitable earth turned out to be S3, classified as medium plasticity clayey sand, liquid limit 37.45, plastic limit 21.64 and plasticity index 15.81 (see page. 6) and 23.19% of the material passing the Nº 200 sieve. A comparison with the values obtained from the other two earth types shows that the important factor is plasticity and the amount of particles smaller than 0.075 mm.

The compression test results are particularly noteworthy. The values obtained in the soil types S1, S2 and S3 point to a behaviour that depends on independent variables.

#### 7.1 Analysis of the behaviour of the «compression strength» variable

First of all the «compression strength» of the earth was analysed in terms of the independent variable «compaction pressure». Test results for soils S1 and S2 show that in both cases the «compression strength» increased in direct proportion to the «compaction pressure» (increase of unit weight or UW), as shown in figures 2(a) and 2(b).
Figure 2a. Mean compression strength–mean unit weight – soil type S1

Figure 2b. Mean compression strength–mean unit weight – soil type S2.

Figure 2(a) of soil type S1 shows a strength of 15.1 kg/cm² for a UW of 1.66 gr/cm³; a strength of 25.49 kg/cm² for a UW of 1.71 gr/cm³, and a strength of 35.2 kg/cm² for a UW of 1.74 gr/cm³.

Figure 2(b) of soil type S2 shows a strength of 14.56 kg/cm² for a UW of 1.57 gr/cm³; a strength of 18.73 kg/cm² for a UW of 1.60 gr/cm³ and a strength of 24.33 kg/cm² for a UW of 1.622 gr/cm³.

This proves experimentally the working hypothesis of the importance of bringing the clay particles closer together to increase the intermolecular electrostatic cohesion force.

As regards the «compression strength» of the soil in relation to the dependent variable «soil type» according to its plasticity and keeping compaction pressure constant at 8 kg/cm², test results of the three different soil types (S1, S2 and S3) show a significant increase in «compression strength» when the «plasticity index» (PI) is higher. A PI of 7.69 gives a strength of 25 kg/cm²; a PI of 13.38, a strength of 32.2 kg/cm², and a PI of 15.81, a strength of 45 kg/cm² (figure 2(c)).
This shows experimentally that the «plasticity index» (at a constant compaction pressure) varies directly with «compression strength».

On the one hand we see the importance of increasing the compaction pressure; on the other, the importance of taking into account the plasticity of the soil to be used. What are the limits of these variables? The limit of the pressure increase is set by the physical properties of the material in question and the mechanical properties of the compacting machine. The soil plasticity limit, for its part, is set by the fact that this plasticity is associated with the shrinkage thereof, and this shrinkage causes fissure problems that are difficult to solve. The criterion will then be to achieve a pressure that guarantees the necessary strength for building a wall, given suitable soil and the necessary pressure. This would be the case of soil S3 compacted to 8 kg/cm$^2$, which gives a mean compression strength of 44 kg/cm$^2$, a value that is very acceptable for a CEB type wall block.

7.2 Analysis of the behaviour of the «water absorption» variable

As regards the dependent variable «water absorption», the most important figures are gleaned from a comparison of the behaviour of the oil-impregnated test pieces and those with no oil. But it should be stressed here that tests with soil types S1 and S2 also showed that there is a relation between water absorption and compaction pressure.

Tables 4, 5 and 6 show clearly for the two soil types that time to start of breakdown of the test pieces and also mean rupture time are related to compaction pressure, increasing directly therewith. Likewise, the test results of soil S2 show higher values than soil type S1 in most cases, except in test pieces without oil and soil compacted to 4 kg/cm$^2$, S2 more than doubling S1 values. This might show that soil type S2 absorbed more oil than S1, creating a thicker film.

As for soil type S3, tests were carried out only on test pieces compacted to 8 kg/cm$^2$, and the results are lower than those of the other soil types.

Rupture times are 3h 23 min and 8h 08 min respectively for soil types S1 (8 kg/cm$^2$) and S2 (8 kg/cm$^2$), whereas the time for S3 is 2h 00 min (see tables 4, 5 and 6). In any case this latter rupture time still clearly outperforms the 40 minutes recorded by the test piece without oil and there is also a significant difference.
in start of breakdown time: 2 min for the test piece without oil and 35 min for the oil-impregnated test piece.

A comparison of the behaviour of soil type S1 and S2 test pieces compacted at 8 kg/cm² with and without oil shows a glaring difference both in start of breakdown time and rupture time. Test pieces not treated with oil recorded a time to start of breakdown of 0h 05 min while oil-treated test pieces clocked up 2h 40 min. As regards rupture time, the mean time for the former was 1h 55 min and 5h 30 for the latter. There is a proportional reduction in the rupture time. This may be because the most important effect of the oil cover is a delay in the breakdown of the first particle layer; once this barrier has been broken the process then follows its normal course. This hypothesis would be borne out by the fact that the test results for unoiled test pieces of the two soil types are practically equal (5 min to start of breakdown and 2h to rupture) whereas oiled pieces record the significant difference reported in the above paragraph.

7.3 Analysis of the behaviour of the «water abrasion» variable

As regards the dependent variable «water abrasion», the test results show a certain similarity to those of water absorption.

The highest values are those for soil type S2, followed by S1 and then S3. This might be bound up with the plasticity of the soils, which varies inversely with oil absorption. The grading of soil S2, moreover, shows that it has a higher proportion of fines, but its position in the plasticity chart shows that a high percentage of them are silt. Likewise, the performance of soil S3 with oil is considerably better than soil without oil.

Three types of material were used in the research work: two soil samples taken from excavations for building foundations and a third from a brick clay quarry

7.4 Alcock's Test

The importance of establishing a relation between the plasticity index and linear shrinkage, according to the Alcock test, lies in the sheer simplicity of this test. It therefore comes in very handy for ascertaining in the field whether or not the available soil is suitable.

Figure 3 shows that both variables do indeed grow in line. This means that we can establish linear shrinkage values as an aid in determining whether or not the soil is suitable.

8. Conclusions

- Results obtained from test pieces of the same type of soil compressed at different pressures show empirically that compression strength increases directly with the compaction pressure of said test pieces.
- Results obtained from test pieces with different soil types also show empirically that compression strength increases with the plasticity of the soil.
- Soil type S3, classified as medium-plasticity silty sand (SM) with a plasticity index of 15.81 and a liquid limit of 26.3 compacted to 8 kg/cm², recorded a mean compression strength of 44 kg/cm², a value very close to the mean strength values of cement-stabilised CEB, also apt for
The resistance of CEBs with no added cement can be improved by increasing compaction and/or compacting earth of higher plasticity. The limit of these variables is set by the proposed compacting technology and the behaviour of high plasticity clays when they lose humidity. Nonetheless, building blocks of greater quality could be achieved by harnessing technology that provides higher pressure for clays of higher plasticity.

The procedure of waterproofing the blocks by surface oil treatment, to stabilise the clay’s water reaction, gave better results in low plasticity clays. Nonetheless, the test pieces of higher plasticity clays outperformed untreated pieces by a factor of three to one. Furthermore the environmental impact of the treatment process is minimal, since the impregnation is done by way of short-term immersion and the handling time is short. Neither does the treated product pose any risk in terms of stability and air emissions because the film is only a few tenths of a millimetre thick and is covered by the coating. The only compounds that might give out dangerous emissions are the PCBs, the proportion of which in oil of this type does not exceed 20 ppm, well below the 50 ppm threshold laid down by international standards.

As regards the water performance of the unoiled test pieces, all tests showed lower values than the oiled pieces and very similar among the different soil types. This result, in view of the fact that all test pieces were compacted to 8 kg/cm2, taken together with the results of test pieces with oil, might indicate that, within the working plasticity range, higher plasticity does not improve water behaviour. This is due to the fact that the breakdown process begins on the surface, where the block is driest and hence most prone to absorb water through the pores.

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**TO FIND OUT MORE**

7. Mellace Rafael; Rotondaro, Rodolfo. Ensayos de suelos. Proyecto de componentes constructivos de tierra cruda.


