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International Regulations and Guidelines Regarding the Use of Earth as a Construction Material

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***Abstract* – New Zealand is a pioneer in the field of earthen constructions and has developed a number of regulations to serve architects, structural engineers and beneficiaries. The regulations adress material resistance, thermotechnical characteristics, on-site testing methods, building techniques, etc. Through the information contained, a framework is created to meet the needs of construction materials with low environmental impact. This article proposes a review of some soil testing methods found in the international literature for its use as a construction material.**

Keywords – earthen constructions, ecological materials, regulations, tests

1. INTRODUCTION

The industrial revolution brought an improvement in technologies and materials in the field of construction, and constructions made of local materials were soon forgotten. After many decades of industrialization, we are starting to experience the harmful effects, manifested through global warming, extreme weather phenomena or the decrease in the quality of life due to pollution. In this context, a possible answer to the current problems can be found by analyzing the technology of construction with local materials using the latest scientific discoveries.

2. EXPERIMENT DESCRIPTION

Perhaps, in Romania, the tectonic characteristics determined a reduction in the scope of application; however we find local materials in our country mainly until the 19th century, when the explosion of the construction materials industry favored the creation of the possibility of reorientation towards novelty elements. Thus, constructions have followed the progress of science, but with the begining of a new era in which global warming accelerates and pollution raises particularly big problems, a reset of engineering concepts in the technology of construction materials is necessary.

At the local level, there are a number of buildings made of stone, wood, straw and earth, cobweb in use and whose construction dates back to about 100-200 years. Despite the proven resilience of these types of materials, in recent decades their share in the existing built stock has decreased dramatically. The cause of this decrease is influenced by several factors:

- Romania, especially the Vrancea area, is prone to frequent earthquakes of significant magnitude. Under the conditions of improper exploitation of buildings made of local materials, they suffered degradation or collapse to a greater extent during or following dynamic loads;

- The lack of homogeneity of local materials makes them difficult to be standardized and ensure a proper quality system;
- The lacunary legislative framework causes certain types of local materials to be avoided by designers and beneficiaries alike;
- In Romania, there is a legislative base for wooden constructions and guidelines for consolidating stone masonry buldings.

3. RESULTS – REMARKS

To the best of my knowledge, the country with the most comprehensive legislative framework for earthen construction is New Zealand. In recognition of this, the New Zealand guideline has largely been taken up by their Australian neighbors as well. The preferred method in these countries is rammed earth stabilized with cement. It is not the most ecological approach; this merit goes to the Europeans (Germany, France, Spain, Great Britain) who are actively studying earthen constructions without the use of additives, but without a legal concretization. Finally, in the area of the American continents things are similar as in the area of Australia and New Zealand, with a preference for the use of stabilized soil.

3.1. The provisions of the New Zealand standard NZS 4298:1998 - "Materials and workmanship for earth buildings" apply to rammed or poured earth and earth bricks

Provisions related to the quality of materials:

- Mixtures must have a maximum of 15% by weight of added Portland cement;
- The soil used must not contain vegetable remains or water-soluble salts;
- Rebars, if used, will be properly protected to prevent corrosion or other damage;
- Only drinkable water can be used;
- The clay bricks are cured in places away from direct sunlight during the first 4 days and can be used after 28 days with the temperature higher than 5°C. They will also be protected from strong winds and rain;
- If cement is used, the bricks are moistened for at least one week to prevent cracking. If the mixture is stabilized with lime, this interval is at least 3 weeks.

Types of mortars that can be used:

- Clay-based mortar. To ensure the optimal quality of the mortar, the clay content is very important. If the percentage of clay in the mixture is too high, sand is added, and if it is too low, stabilizers (lime or cement) are used.
- Cement-based mortar with a sand-cement ratio between 6:1 and 12:1

Before being used, the material must undergo some tests. For this purpose, a sufficient number of test samples made from the soil or the mixture are created, which are then cured for 28 days, under the conditions presented previously. Also, in order to control the quality, the tests will be repeated at the following intervals:

- When the granulometry changes;
- If the soil source changes;
- For every 5000 bricks manufactured;
- For every 200 cubic meters of rammed or poured soil used.

In situu tests can be carried out to reveal the characteristics of the material (compressive strength), resistance to repeated cycles of wetting, erosion or shrinkage.

The test to determine the characteristic compressive strength (f') involves testing the test specimen under axial load. Its height/thickness ratio must be equal to 1, otherwise the result will be adjusted with the value of 0.7*ka, where ka is the height/thickness ratio. A minimum of 5 samples are tested and a set of values denoted by X1...Xi...Xn is obtained and recorded in ascending order, and then the arithmetic mean of the values obtained, denoted by Xa, is calculated. The next step involves determining the standard deviation using the formula:

$$X_s = \sqrt{\frac{\sum X_i^2 - nX_a^2}{n-1}} \tag{1}$$

and then the characteristic compressive strength with the formula:

$$f' = \left(1 - 1.5\frac{X_s}{X_a}\right) \tag{2}$$

A graduated container of water and a wick are used for the erosion test. The wick has one end submerged in the water and the other end is left hanging on the outside of the vessel. Through capillarity, the wick soaks up water and forms drops at the free end that fall on the test piece from a height of 40 cm. Before testing, the sample must reach maturity at a minimum of 28 days and is positioned on an inclined plane with a slope of 1:2.

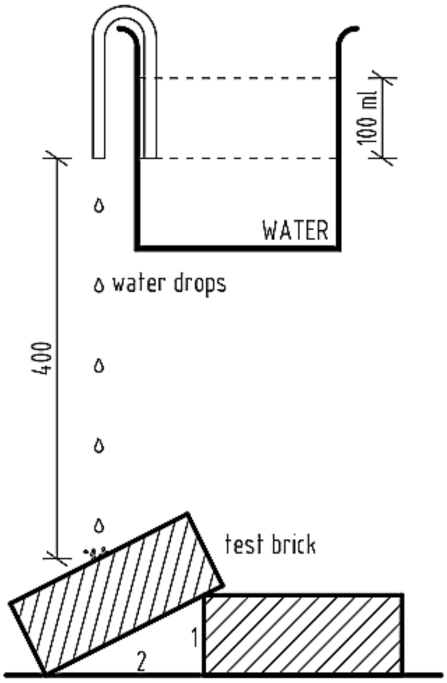

Fig. 1 Erosion test

After dripping 100 ml of water, a cavity will have formed formed wich can be measured with a rod and a score is given:

- Between 0 and 5mm – 2 points;
- Between 5 and 10mm – 3 points;
- Between 10 and 15mm – 4 points;
- More than 15mm – 5 points.

A score greater than or equal to 5 means that the soil mixture is far too susceptible to erosion and needs to be improved.

For the water resistance test, a vessel that has a surface area 50% greater than the surface area of the test specimen is used. The water level in the vessel is 12mm and the sample is submerged and supported by 2mm spacers, so that only 10mm of the sample size is under water.

After 4 minutes, the test piece is dried, and after that, a visual assessment is made, noting any of the following:

- If cracks appeared in random directions;
- If star-shaped cracks appeared;
- If local swellings appeared;
- If gaps appeared;
- If the sample lost some of it's mass;
- If efflorescence appeared, generally white.

The procedure is repeated 6 times, and after the last iteration, after drying, the results are satisfactory if none of the mentioned flaws appeared.

For the shrinkage test, a box with dimensions 50x50x600mm is built. Take the mixture for which you want to find the percentage of shrinkage and put it in the box. It should be kept moist for 7 days and then left to dry for another 21 days. After curing, the length of the sample is measured and the shrinkage can be calculated with the formula:

$$S = \frac{S_m * 100}{600} \tag{3}$$

Where S is the contraction in percentage and Sm is the contraction measured as the difference between the length of the box and the final length of the sample. This test can be run in parallel to test multiple mixes by building multiple adjacent boxes. A high shrinkage of the mixture means a higher percentage of clay.

Accepted values for shrinkage according to NZS 4298:1998 are:

- Less than 0.05% for rammed earth;
- Less than 0.2% for cast earth;
- Less than 1% for mortars with cement addition;
- Less than 3% for cement-free mortars.

3.2. Other tests mentioned in the international literature

For the sedimentation test, a transparent container with a lid and a volume greater than 500ml is used. The soil is placed inside and then water is pored over. Shake the container vigorously and then let the contents settle. The constituent particles will settle in order of size, those with the largest size at the bottom of the container. With the help of this test, the clay content of the soil can be assessed, but with reduced accuracy. However, some phenomena can be observed that may indicate considerable clay content:

- The granulometry of the soil can be identified and the thickness of each layer can be measured. As previously mentioned, this procedure has low accuracy, which means that for the exact determination of the granulometry, laboratory tests are necessary;

- Clay swells in the presence of water. If a line is drawn on the wall of the jar to indicate the initial level of the soil before shaking the container and after 24 hours of sedimentation and the final level is higher than the initial level, this indicates high clay content.

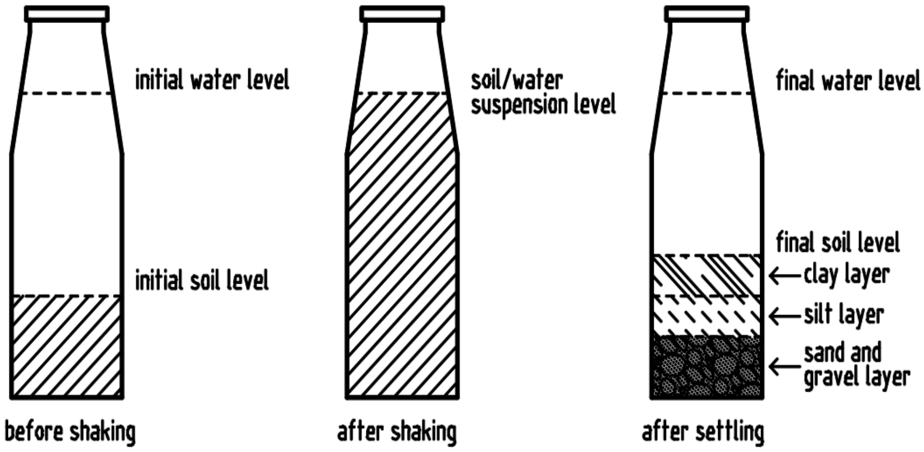

Fig. 2 Sedimentation test

The cylinder or cigar test can also reveal clay content. To perform this test, mix the soil with water until a paste is obtained that does not stick to the hand when shaped and has the consistency of plasticine. This paste is processed manually by pressing, not by rolling, on a work table until some pieces of approximately cylindrical shape with a diameter of 2.5-3cm and a length of 30-40cm are obtained. They are kept suspended at a height and the pieces that brake off are put aside and their length is measured. If they are longer than 15cm, the percentage of clay is sufficient and the soil can be used. You can also take a piece of the resulting paste and shape it into a cylinder with a diameter and height of approximately 3cm. It is held in the palm and the center of the circle is pressed with the thumb to form a concave shape. Water is placed in the obtained cavity, and the speed with which the water drains is an indicator of the clay content, the slower it drains, the more clay the mixture has.

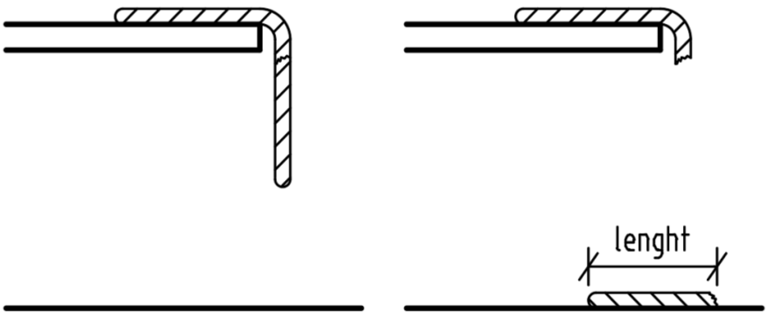

Fig. 3 Cigar test

4. CONCLUSION

Considering the use of soil as a construction material, with the help of in situ tests, a preliminary assessment of the quality level of the material can be done in order to reduce the number of tests carried out in a specialty laboratory. Also the tests performed can help to improve quality control ensuring optimal results.

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Note:

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