Sustainable Building Materials and Technologies of Stabilized Earth

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Abstract: Through Centuries clay was used as a building material; it is one of the most known materials worldwide for its thermal properties, its wide availability and low cost. In Algeria, the use of clay in construction is very old; it is used not only in companions in the countryside but also in cities. Almost all the so-called traditional constructions are made with soil associated with other extra materials such as hay or mineral additives. Abandoned recently because of its low resistance to water, clay is becoming again a good material due to new techniques of stabilization and promotion of the reinforced earth material for the future. One of the major concerns was to improve the mechanical properties of the clay while keeping its essential advantage of a low cost and sustainability. For this purpose, some methods and techniques are developed such as stabilization carried out in many countries, and promoted by the United Nations. Usually earth has thermal and economical properties higher than those of the concrete or other manufactured materials. Housing developers are content to meet minimum standards of insulation, without using the heating system still bringing comfort. We cannot rely only on highly sophisticated techniques to design a more efficient housing, but by using natural elements such as (sun, wind, clay and vegetation). Such an idea inserts man in his environment and truly is sustainable. Traditional housing, present beyond its charm, architectural features allowing it to naturally adopt the climate and use the properties of local materials. From previously implemented solutions, it becomes a technique of reinforcing clay construction, improving modern processes, adopting the needs of contemporary living and comfort. Housing and climate become interdependent through a better understanding and to a high mastery of the well-tempered buildings. Design a building as a protective shell, providing climate control is optimized with respect to natural features and local materials but not to stand against climate and nature brutally using a heater or an air conditioner.

Key words: technology, construction, clay, building materials, sustainable, environment, thermal comfort

1. Introduction

Of all times, earth has been used as a building material; it is one of the best-known materials throughout the world for thermal properties, its wide availability and low cost. In Algeria, the use of clay is very old; it is used not only in companions, but also, in cities. Almost all so-called traditional constructions are made out of earth associated with other mixed materials such as plant or mineral additions.

Discarded in the past because of its low resistance to water, the earth is in the process of using new techniques of stabilization and the promotion of the armed earth is a material of future. One of the major concerns has been to improve the mechanical properties of the earth while retaining its essential advantage: a low cost price.

To this end, certain processes and techniques have been developed; such as stabilization carried out in many countries, and promoted by the United Nations; which has shown that the earth constitutes a topical material, which, Most of the cases, possessed thermal and economic properties, clearly superior to those of cement and concrete. Until now, the designers have only satisfied minimum standards of insulation, leaving the heating system to bring comfort. It is possible without using very sophisticated techniques to design a more efficient habitat, using natural elements such as (sun, wind, land and vegetation). Such an
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approach, placing man in his environment, and in this truly ecological sense, that man must end up with the new rules of Art.

The traditional habitat, present beyond its charm, architectural features allowing it to protect itself naturally from the climate. Indeed, the absence of heating means obliged manufacturers to use at least the properties of local materials. On the basis of the solutions formerly implemented, they were improved by modern techniques and processes, and adopted for the needs of the contemporary habitat, thus, what was good and natural became reasoned, habitat and climate became solidary thanks to a better knowledge, and to a high mastery of the thermal values of the buildings. “Designing a building, as a protective envelope, ensuring a climate control, is to optimize the relation to natural data but not to fight brutally against the climate using artificial heating” and cooling [1].

2. The Architecture of Clay

In these multiple human settlements, land has been used to build urban and rural dwellings, this same material has also been used for a hundred years to raise the most ambitious and prestigious monuments, the most extensive and most useful for material developments and for Spiritual Communities. Our country (Algeria) possesses for centuries and especially in the south, an exemplary architecture built without architects. The builders of the region with their own hands, their own means fought against the climate using local materials, they built original cities of extraordinary architecture. All the occupants of these regions: masons, carpenters, sociologists and religious worked together to build their homes.

“Vernacular techniques => local materials and resources
Local or regional architecture
With many variants (materials/techniques).”[2]

2.1 Comfort

The dwellings have a certain thermal comfort, in spite of the great temperature variations outside the building, whether day or night. The thickness of the walls ensures a high thermal inertia; it isolates the interior and maintains a very regular temperature in the rooms.

Fig. 1a shows thermal comfort in earthen buildings in southern Algeria during the summer season. Temperature inside the building varies from 22-26°C. While outside the construction, it is very hot, the temperature in most of the time varies between 40-45 in the shade.

Fig. 1b shows thermal comfort in earthen constructions in southern Algeria, during the winter season. While outside of the building, it is very cold, the temperature varies between 2-6°C and in most cases the winds of sand blow from all over, in this whole region.

3. Technical Study

3.1 Concrete Stabilized Clay (C.S.C)

Concrete stabilized clay (C.S.C short term), also known as “geo concrete” or “sol-cement”, is a material obtained by mixing a soil (or several) with a particle
3.2 Main Benefits

The main advantage of land use is the low cost of the base material:

1. It is available locally in most cases in abundance hence an immediate economy at least in cost of transport.

2. The purity of the clay is neither necessary nor desirable, so that most soils are likely to be established, including soils unsuitable for conventional bricklaying, and in many cases soil extracted from foundation excavations can be used.

3. The material has much better thermal characteristics than conventional cement concretes, especially for insulation (thermal resistance about two to three times better than that of cement concretes).

- Economy on aggregates: When soil can be extracted near the site, it costs less than the sand and gravel used in the concrete agglomerate.

- Economy of cement: By way of example, 80 kg of cement per cubic meter of masonry against 120 kg for walls of hollow agglomerates metered at 180 kg of cement per cubic meter.

- Economy on mortar: Grouting, sand and cement is more economical than sand and cement mortar uses in ordinary masonry.

- Economy in manufacture: A covered storage area is not necessary for the protection against the sun of fresh blocks, which can be covered with mats and sprinkles without risk of breakage immediately after their manufacture, which is not the case for agglomerates.

- Economy in coating: Thanks to the modern techniques of soil stabilization; it is possible to construct buildings of a satisfactory strength and durability for maintenance neither too frequent nor too important. “With a soil of suitable granulometric composition, compressed with optimum water content and stabilized by means of a suitable substance, it is possible to obtain a material as durable as the ingredients usually used for hard construction” (Report of the United Nations, 2015) [3].

3.3 Stabilization

The stabilization of the earthen concrete allows while preserving the natural properties of the natural material to confer on others. On the simple (Toub), earth concrete offers both better technical qualities and greater durability. The stabilization of earthen concrete is essential to make this material less sensitive to changes in its water content and to prevent it from being transformed into mud or crumbling under the action of moisture and Undergo a shrinkage such that large cracks open and the coatings become detached.

3.3.1 Cement Stabilization

Provided the soil to have an adequate particle size, it can be stabilized by mixing it with an adequate amount of cement.

- The ideal floor: The ideal soil is a mixture of sand, silt and clay with a well-balanced granulometry, the best results have been obtained on land containing 75% sand and 25% silt and clay, the clay representing Less 10% of the mixture. In general, soil suitable for cement stabilization may contain at least 45% sand and 55% silt and clay and not more than 80% sand and 20% silt And clay, between 0 and 20.

- Preparation: The soil is spread in thin layers on a protected area of the rain, in order to lose by drying its natural moisture, when this soil is sufficiently dry, it is crushed with shovels and then screened through a mesh screen 4.76 mm. The material passing through the screen is the soil that will be used to make the stabilized concrete. The soil must be thoroughly pulverized in order to mix thoroughly with the cement. Once the cement is in contact with the water, the soil must be dry as well as...
the soil-cement mixture. Once the mixing is done, the water is added and then the concrete of earth is placed in its mold as quickly as possible in order to prevent the cement from making a grip outside the mold. The cement reaches most of its strength during the first 7 days, so it is important that it be kept, during this time, in a moist environment, which can be practically achieved by covering the watering regularly. The final resistance of these cinder blocks will depend, in fact, on the period during which they will be kept in the wet state.

3.3.2 Stabilization with Lime

Principle: Lime stabilization is particularly suitable for clays with which lime reacts by forming cholanic compounds. It is also possible to stabilize limestone, sandy or loamy clays with clay gravel or clay sands, that is to say with soils having a plasticity index greater than 12. This during the chemical character of the stabilization with lime does not occur for all types of clay, it is therefore important to verify experimentally that this stabilization reaction actually occurs. Clay soils are generally fairly compact. Lime, by breaking the various connections, makes the soil easier to mix.

Preparation: The soil must be dried before being ground and sieved. When the soil is well pulverized, it is possible to mix earth, lime and water. The water must be in sufficient quantity for the mixture to be perfectly moist. This first mixture is stored in a moist environment for a day or two and then re-mixed in order to break the bonds that may remain between the clay particles. Then it is implemented definitively. Like cement, the lime must be in a moist environment to acquire its maximum strength. The lime-stabilized cement blocks must be kept moist for one week, two weeks if possible, and then kept away from the sun for another week. Cement-stabilized blocks acquire their maximum strength only after a relatively long period, of the order of 6 weeks to two months.

3.3.3 Stabilization with Lime and Cement

Principle: Some soils have a slightly too high clay content to be cement stabilized. The addition of lime may for these same soils, facilitate operation without waterproofing these soils or increasing their strength. For these soils, it is advantageous to use as a stabilizer a mixture of lime and cement, the usual mixtures contain 50% lime and 50% cement.

3.3.4 Stabilization with Asphalt

The stabilization of the soil with asphalt gives good results for cast blocks; the mixing is more difficult when it comes to compressed blocks or cast walls.

3.3.5 Stabilization with Straw

Straw was frequently used in the making of earth bricks. H. Fathy suggests that fermentation of straw in a moist environment produces a lactic acid that makes the brick stronger and less absorbent. However, the straw must have had time to macerate in water so that it can putrefy. On the other hand, non-rotting straw has channels that allow water to evacuate more quickly during the drying period. This makes it possible, particularly for clay soils, to reduce shrinkage cracks. Stronger fibrous products as reed and mainly hemp can improve significantly the strength and also the thermal insulation not only for the hot climates.

3.4 Soils

The soils are composed of mixtures of varying proportions of four kinds of elements: gravels, sands, silts and clays. The behavior of each of these constituents is specific to it and, for example, when subjected to variations in moisture some change in volume, on the other hand, no. The first are unstable and the others stable, this notion of stability, is ability to withstand alternations of humidity and dryness, without variation of properties, is fundamental for a building material.

3.4.1 Gravels
They consist of pieces of rocks of varying hardness, the size of which is between 5 and 100 mm approximately. They have a stable constituent of the soil; their mechanical properties do not undergo any significant modification in the presence of water. The great volume and size of gravels deteriorate the thermal insulation but in warm climates it is indifferent.

3.4.2 The Sands

Are made up of mineral grains whose size is approximately between 0.080 and 5 mm. Stable constituents of the soil, they do not possess, when they are dry, cohesion, but present, on the other hand, a high internal friction, is a high mechanical resistance of friction to the relative displacements of the particles which compose them.

3.4.3 The Silts

Consisting of grains whose size is between 0.020 and 0.080 mm approximately, do not possess cohesion, when they are dry. They have a resistance to friction, generally lower than that of sands, they show humidity, good cohesion and can, when their moisture varies, undergo sensitive variations in volume, swelling and shrinkage. Gravel, sand and silt to a lesser degree are therefore characterized by their stability in the presence of water. Dry, they have no cohesion and therefore cannot be used alone as a material in the building blocks.

3.4.4 Clays

Constitute the fraction; the finest of the soils (less than 2μ) do not possess at all, the same characteristics as the other aggregates. Most of the grains that constitute them are small minerals [4].

4. Experiences

Experience is the only way to achieve reliable and sustainable solutions, science itself is experience-based, large developed countries are investing enormous budgets to create new Last one a master country of the world.

4.1 The First Experiments

To converse the benefits (availability, economy, thermal) of land use and improve technical characteristics to meet the demanding specifications of “modern” materials have been attempted:

4.1.1 At International Level

Research and pilot applications were carried out after 1945, during the reconstruction period in France, on the branch of the B.T.S banche. In the late 1950s and especially with the support of the United Nations (1959-1962), applications were made, especially in Latin America, with the help of small hand-operated manual mechanical presses (CINVA type-RAM). These presses are of low cost but allow for a still modest compaction pressure, and consume labor. This is why we advocate this type of pure material for very small-scale self-construction operations [5].

4.1.2 At National Level: The Algerian Experience

In Algeria, the use of land is a very old tradition; it was used not only in rural companions but also in cities. Almost all so-called traditional constructions are made with earth associated with other make-up materials such as vegetable (straw ...) or mineral additions.

Rejected in the past because of its low resistance to the action of water, the earth is becoming, thanks to the new techniques of stabilization, a material of future. The valorization of local materials in Algeria to always remain only in places much more special in the South Algerian gradually this temptation to use local materials begins to expand since independence by citizens, builders in villages, where rainwater does not influence the strength and durability of this material. Mixed with straw or ash, the earth was the most usable
material recognized in the construction of Algerian cities and especially the cities of South Algeria.

Serious research has been carried out by the CNERIB (National Center of Studies And Search Integrated of Building. They focused on the study of affordable building techniques by unqualified personnel (self-construction) to rehabilitate certain traditional know-how with known local materials (Toub, Timchent, etc.), and the stabilization of materials and constructions. In this context, several prototypes were realized in several cities such as Biskra, Tamanrasset, Bechar and Adrar. The basic scientific work already carried out has greatly accelerated progress in this area. As a result, some province and town national companies have begun to equip themselves with the materials necessary to implement housing programs based on local materials.

It should be noted that the Ministry of the Interior has been interested in this product and has already installed CSC production machinery in Cheraga and in the South in collaboration with CNERIB. Work carried out by the central research and control laboratory for the development of special cements from local materials that can withstand natural aggressive actions. This work made it possible to obtain different types of cements, namely: Mr. Ghazali, Ministry of Housing and Urban Development, stated that: “The future lies in the use of local materials, so we must now try to adapt the construction industry to this type of construction”.

4.2 Practical Attempts in Algeria

An attempt was made to Zéralda on housing, then to Mostépha Ben Brahim on several, constant to pour earth containing a small percentage of cement in a traditional formwork: It is thus the traditional technique of the adobe, improved by a small addition of cement. In this case, the resistance of the formwork to the lateral thrusts necessarily limits the compaction pressure. L N T P B (National Laboratory of Public Works and Building has) carried out a series of preliminary soil characterization tests (from the Ouargla region in particular), unfortunately these tests have not been followed up and have stopped at the level of protection of a few blocks in the laboratory. In the 1980, the INERBA became Center National Integrated Studies of the Building Began the Research, on the use of the local materials (Concrete of Stabilized Clay, Gypsum and plaster concretes, and concretes recycling of the debris of Ech-Chlef And recently stabilized dune sands). This work combines tests in laboratories and experimentation through prototypes.

For the stabilized earth concrete, the different phases of INERBA’s work were as follows:

1. Search bibliography, compilation, analysis and synthesis.
2. Laboratory tests, the land was collected and sampled in several cities of the South like Adrar, Reggane, Bechar, Touggourt, Biskra, Tamanrasset and Cheraga.

They have been the subject of detailed analysis and have developed compositions and formulas for concrete and stabilized earth mortars according to: - the characteristics of the soils encountered, - the stabilizers available - uses in construction (bricklaying, plastering, etc...). The composition guides, curves, spindles, and abacuses have been elaborated.

3. Mathematical modeling (thermal and mechanical), calculation and optimization of solutions:
   - A thermal parameter study was carried out using a program simulating the thermal behavior of buildings on a computer. It led to a "thermo-economic" optimization of wall opponents.
   - Five types of roofs, for types of load-bearing walls and six types of functions have been studied and developed in the design and calculation of mechanical strength and from the economic point of view in terms of material consumption Such as steel and cement to achieve optimization.

4. the complete construction system has been studied and rationalized for the various scenarios and maximum economy of steel, cement and formwork.
5. Conclusion and Recommendations

By analyzing why the use of reinforced concrete in construction in southern Algeria, knowing that the latter and a material foreign to these regions and does not integrate with the environment, use has yielded bad results at the thermal and sound insulation level.

Concrete and a marriage between concrete and steel, these two materials are not available in the southern regions, which implies another problem of considerable magnitude is the North-South transport problem which paralyzes thousands Trucks without limiting the problems of the road. Why all this, while the earth sustainable and ecological materials and barely hundreds of put on the very premises of constructions. The mechanical characteristics of the earth do not allow the replacement of cement concrete, but the techniques of soil stabilization make it possible to deal largely with cement concrete (cement concrete) and to replace it in most projects Located in the hot zone of the territory, in particular the south of the country.

The earth building blocks tested had sufficient compression strength (20-50 kg/cm²) 2-5 N/mm². It is far enough, even in cities, up to a building height of 2-3 stories. Because in order to have enough thermal capacity, in the hot zones the walls and (cupola) roofs have to be rather thick (min. 30-50 cm). Otherwise earth materials can be neglected in highly urbanized, industrialized areas. Besides thermal properties of earth materials their strength is also satisfying to solve the housing problems of billions around the world in the hot zones. It is really a great expected result. Even larger structures would be built by improving the tensile stress with reinforcement, but the practical success is not yet clear [6].

According to most seminars on vernacular architecture and the use of local materials; Several specialists: Architects, Engineers, Economists, Entrepreneurs, Lawyers, Politicians, representative of several national and international companies of
realization and heads of the units of production of materials, with the presence of several specialists and invites from abroad. The goal is to discover the obstacle that causes people to build concrete weapon cement, with all these disadvantages and its highest cost compared to the construction of local materials such as: Concrete of Stabilized Clay (CSC) Stone, plaster, gypsum, etc. ... The results obtained according to the studies and analyzes made on the use of local materials are:

The theoretical economic study proves that the cost of a house constructed of reinforced concrete (structure and cover of reinforced concrete, cement concrete block filling) is very high compared to that built in BTS (reinforced concrete structure, vault and cupola roofing, stabilized earth brick filling).

Engineers: The technical study favors the use of local materials by relying on the positive results of the tests carried out in the laboratories on the thermal and acoustic insulation and the mechanical strength of the brick in BTS and the vault in plaster.

Based on the practical experience of entrepreneurs in the region: the cost of a CSC home is higher than that of a reinforced concrete house, due to the shortage of local materials Such as: stone (absence of quarries), CSC brick, plaster vault (absence of local production units), lack of manual or mechanized parapause, lack of skilled labor.

Architects and urban planners: the reinforced concrete construction in the South tore the natural site, exempted its integration with the environment has shared the urban fabric of the city into two parts, old part that is built of earth, durable natural material with its original style, shape, rhythm and local architecture that is integrated with the site. Another part contemporary architecture that is constructed of reinforced concrete and cement brick, artificial materials foreign to the region, which made a complete break from the old urban fabric.

Juristic: one of the causes that favor the use of reinforced concrete and disadvantage the use of CSC in constructions is: the absence of laws that manages the construction with it CSC; Especially at the level of the Technical Commission of Control during the studies.

Politicians: they are ready to take charge of all the problems that impede the use of local materials, in particular Concrete of Stabilized Clay (CSC) and to apply the recommendations, which give the possible solutions to enhance the durability of local materials.

5.1 Recommendations

The recommendations made in order to valorize and use the local materials are:

Local consultants, local businesses and local people should be made aware of the rational use of local materials. To this end, local authorities should, for example, of these materials. Projects should be recorded and then realized as they mature, mainly in the context of P.M.I. (Small and Medium Industry), both public and private. It is also necessary to identify, register or undertake large-scale construction programs and to formalize multi-annual supply agreements between the production units of the materials and the various contracting authorities concerned. Reserving a significant share for direct sales for individual constructions. Revalorize old quarries and create new ones for the production of local building materials. Build local production units of stabilized earth brick and vault and gypsum vault. To put at the disposal of all the citizens manufacturers or contractors machines of production (parapets) manual or mechanical with an affordable price. Open a new specialty in vocational training centers in South Algeria like (Technician and superior technician and builder in CSC) — prepare a practical technical guide of construction in B.T.S and put it in the hands of teachers and pupils of the vocational training. Draw a house model catalog to give users the freedom to build their homes to their tastes and to better serve as a practical phase for students of vocational training.
References


