Bioconstruction Workshop

Quito, Ecuador, 8 to 17 June 2018

Co-funded by the
Erasmus+ Programme
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IVS for Climate Justice Don't just say it! Do it!
Volunteering to Create a Network of Knowledge through Ecological & Sustainable Practice

Bioconstruction Workshop

Report

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Workshop hosted by the FEVI Fundation in Quito, Ecuador, from 8 to 17 June 2018.

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PROJECT INTRODUCTION

The project following the aims of the White Paper in 2016 and the Action Plan 2017-18; seeks to provide new skills and revive traditional techniques in the field of environment and sustainability, while taking into account the ways in which the network can address poverty reduction and health promotion. It uses the pre-existing campaign IVS for Climate Justice, established in 2015 as a banner to highlight the actions of different IVS networks on environmental sustainability and to emphasize the contribution of IVS projects to the achievement of the SDGs.

IVS for Climate Justice is a worldwide campaign taking place in over 100 countries, coordinated by CCIVS (A global network focusing on International Voluntary Service), bringing together the activities of five International Voluntary Service networks, CCIVS, Service Civil international (SCI), The International Building Organisation (IBO), Alliance of European Voluntary Service organisations and Network for Voluntary Development Asia (NVDA). It engages volunteers with local communities to work on grassroots projects that combine manual work and awareness raising actions. These address issues such as climate change, carbon offset, environmental sustainability, protection of ecosystems, water and soil management and conservation.

The main objectives of the project are to:

- To develop IVS organisations' youth workers and trainers capacity of acting as multipliers in their regions and in their organisations
- To strengthen participation in the global IVS network and connection between organisations who may also make part of different networks who would not normally work together (CCIVS acting as bridge between these networks) and with external stakeholders
- To revalorise traditional / alternative farming and construction techniques
- To raise awareness about the effects unsustainable food production and housing and their contribution to Climate Change

The project incorporates 5 phases with the Bioconstruction workshop as part of the second phase, focusing on practical and theoretical work, with emphasis on building with earth.

In the field of construction, bio-construction offers buildings with an advantageous life cycle, materials used are obtained directly from nature (or have been minimally processed industrially) and the means of production consume very little energy, resulting in a very low emission process.

The process to build is close to the basic methods of construction and is suitable for assisted self-construction, as it does not require specialization of the workforce.

With millennia of tradition, building with earth is sustainable, cheap, efficient and healthy. Earth, an abundant and often free raw material, is perhaps the best material for housing construction. Earth acts as a regulator of humidity and temperature, as well as filtering out negative influences from the environment.

GOALS

The main objective of the workshop is to show the basic concepts of construction with earth systems (eco technologies), carrying out an exchange of knowledge so that the attendee has tools that allow them to replicate the acquired knowledge in other communities. The following points are also objectives of the course:

- To share knowledge about constructions with a low environmental impact,

- To raise awareness about environmental problems and propose alternatives for mitigation and adaptation to climate change, such as bio-construction,

- To learn about low-cost techniques, which can be adapted to diverse environments, helping to improve the quality of life and health of the people who use them.

Premises:

- To achieve a harmonious design for each place and situation,

- Taking advantage of passive solar energy as the most ecological and economic form of thermal comfort in a home through Bio-Climatic Architecture..,

- Promote constructions made with non-industrialized materials, which nature provides in the immediate environment,

- To use ecologically healthy materials (which do not contaminate the environment or its inhabitants and achieved without harmful use of people, land or resources...),

- To create designs that can be integrated into nature (that when no longer used return to the earth in a prudent period of time without leaving pollutants to future generations),

- To check that recyclable materials are not pollutants,

- To build economically viable constructions, (those constructed without ostentatious squandering of materials and energy),

- Design long-term sustainable constructions (with the minimum cost of maintenance).

PROGRAM

Methodology:

Theoretical and practical sessions took place through 'Learning by Doing', aided by tools such as group work, collective reflection, talks and videos to provide an experiential approach, with dialogue and by getting to know the earth.

The Programme of the activity

BIOCONSTRUCTION Workshop ACT 2

Days

	1	2	3	4	5	6	7	8	9	10	11	12	##
	Breakfast												
Morning				Introduction workshop Compatibility of expectations	Visit to Quito	Selection and recognition of soils	Introduction to Earth construction techniques	Practice: Adobe	Practice: bahareque and rammed earth	Practice: preparation of mixtures and plastering colour pigments	Basics of passive solar architecture		
				Coffee Break									
Morning	Arrival team	Prep team	Prep team	Introduction to Bioconstruction I Intro to the SDGS I	Visit to Quito	Practice: test: Caraza	Visit and practice: local bioconstruction project, La Tola Chica Tumbaco	Practice: Adobe	Practice: bahareque and rammed earth	Finishing and decorations	Climate: classification of different types of climate zones and manners to transmit heat and thermal heat	Departure pax	Departure team
		Lunch											

Afternoon		Prep team	Arrival pax	Presentations pax	Visit to Quito	Practice: test: Caraza	Practice:Adobe	Practice: Bahareque	Materials, paints and finishing techniques	Finalizing decorative elements	Seismic resistant structures	Evaluation team and next steps for follow up	
				Coffee Break									
Afternoon				Visit to Lumbisi and community welcoming	Group reflection	Practice: test: Caraza	Practice:Adobe	Practice: Bahareque	Practice: preparation of mixtures and finishing touches	Finalizing decorative elements	Evaluation and presentation of constructions to the community		
				Evaluation groups									
				Team meeting									
	Dinner												
	Evening activities												

THE TEAM

The work team consisted of four people: Professor Ariel Gonzalez from the University UTN of Santa Fe; linguistic mediator and co-trainer Borja Franco; Professor Engineer from the Pontifical Catholic University of Ecuador and member of the Pro Terra network Patricio Cevallos and local bio-builder, Mr 'Don' Virgilio. The team were supported by the local hosts FEVI Foundation.

Professor Ariel Gonzales

Mr 'Don' Virgilio

Professor Engineer Patricio Cevallos

Co-trainer Borja Franco

WORKSHOP - BETWEEN THEORY AND PRACTICE

Introduction to Bioconstruction

When talking about bio-construction, we are not only talking about the construction of a shelter or housing, but also about the intervention of the human being in planetary ecology. It is not to only look at what is happening inside the occupied space, but to know that every action taken affects the whole planet and directly or indirectly affects all living beings. By the simple fact of occupying a space, the human being leaves a footprint; our current knowledge allows us to see more or less which actions will not negatively affect future generations.

The concepts of bio-construction places life as the priority element (not the market (market-construction), nor the individualism of man (anthropoconstruction), in the complex system that unites all the actions that communities carry out to generate life (food, clothing, housing, education, leisure, communication, etc.). The planet is like a big 'house' with which we must dialogue to take care of each other. Focusing on the aspects of building for human shelter, we recognize the great environmental impact this normally causes: it is here where the principles of the bioconstruction help to build more sustainable spaces, looking for an architecture and form of building that collaborates to stop climatic change.

> *Bioconstruction (f) means respect for nature, health and well-being, sustainability, local materials (raw, no energy wasted in production and transport), self-sufficiency, harmony with the environment, low environmental impact, appropriate and targeted techniques.*

The use of materials in the construction of buildings has, in all its phases' impacts on the environment: extraction of raw materials, transport, handling, commissioning, operation, end of life and waste disposal. Planet Earth is endangered by the consumption of non-renewable resources, the energy crisis, CO_2 emissions, the carbon footprint and climate change. In the production process of modern building materials, many factors are taken into account, including the extraction of raw materials, non-renewable resources and the use of energy required for their industrial transformation.

Cement is the most used material after water: 3 tons per year per person according to the "World Business Council of Sustainable Development", which means 3 tons of CO_2. Climate change produces a chain of effects, from the greenhouse effect to global warming, floods, droughts, melting glaciers, severe weather phenomena and so on. In this setting, the objectives of bio-construction are: the reduction of CO_2 emissions and carbon footprint, the use of renewable energy sources, the reduction of the use of raw materials, waste reduction and improvements in people's quality of life.

We are sometimes aware of the toxins we eat with the food we get from supermarkets, the sustainability of a means of transport or in the making of clothes, but we are not aware of the many unhealthy effects contained in building materials and in the methods, we use to build. The industrial revolution accelerated the process of creating unhealthy spaces inhabited by man. Although technology has raised comfort standards, many ecological and healthy spaces have been lost. By recovering natural ways of building, we can limit the damage to the planet without losing the acquired comforts.

Bio-construction is not only the organic house, self-built by a certain social sector and isolated in sectors surrounded by virgin nature, but is also a proposal for those who understand that another way of building is possible.

Some of the different techniques used in bio-construction are: sustainable design, the use of wood and bamboo, green roofs and construction with earth. Sustainable design follows the principles of energy efficiency, insulation and orientation, for a house of reasonable and flexible dimensions. Wood and bamboo are natural, recyclable, biodegradable materials that need little energy, with low environmental impact and a reduced carbon footprint. Bamboo is one of the fastest growing plants in the world, it has a higher compressive strength than wood, brick and cement, and a higher tensile strength than steel. Green roofs reduce the transfer of rainwater, are energy efficient and improve air quality. The use of soil is a powerful tool for human beings to build their habitat in an expressive way and using local resources. In fact, a large part of humanity lives in earthen buildings.

The increasing industrialized and globalized models of urbanization used when conceiving a city are factors that contribute to the disappearance of traditional knowledge and practices.

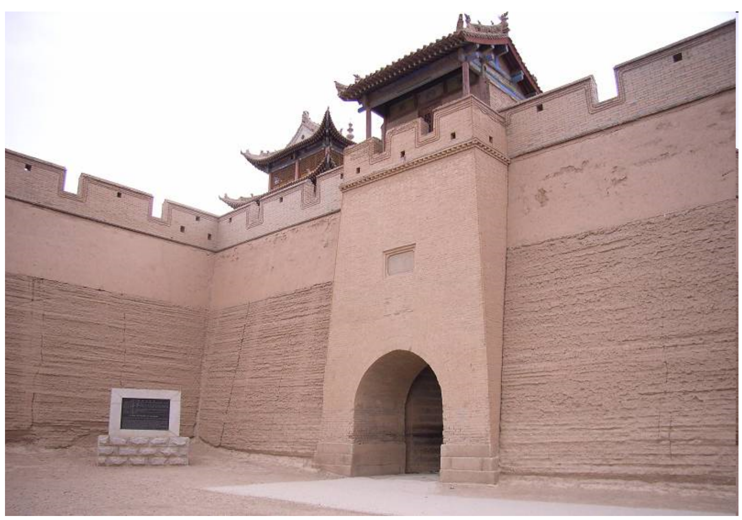
It is therefore very important that local actors manage local needs and propose a form of construction that effectively connects people, collectively to their land. By this action, the right to build with natural materials is reinforced.

Building with Earth

Earth has been, is and will continue to be one of the greatest materials used by humankind to build habitats and to shape the environment.

© Mariordo (Mario Roberto Duran Ortiz)

La gran mayoría de las pirámides milenarias tienen su nucleo de tierra.



La muralla China, construida parcialmente con técnicas de tierra.

Casbah al sur de Marruecos

Centro histórico de la ciudad de Troyes, Francia.

Vivienda social actual en tierra, en la ciudad de Rennes,

Escuela Bioclimática construida en tierra.

La actual y emblemática Capilla de la Reconciliación, en Berlin.

Escuela de tierra apilada y bambú en Bengladesh

Hotel en Jujuy – Argentina

Vivienda en Piriápolis – Uruguay

Vienda moderna en tierra en Chile

The importance and potential of earthen architectures are known and recognized and increasingly encouraged: recent research confirms the advantages of using earth as a building material. Its use contributes to the reduction of greenhouse gas emissions, thus mitigating the risks associated with climate change.

There are no global solutions, technologies, and models that can simply be exported from one place to another: historical data, cultural practices and new technologies can inspire innovation and structure interventions to be adapted to natural, cultural, social and economic environments. This is why it is so important that innovations and applications are manageable by local actors and that they satisfy the need to build in a way that effectively connects people collectively, with their territories.

We can focus on the construction of new buildings or the restoration of existing ones and, in both, take into account aspects related to the paradigms of bio-construction. When thinking about and planning the project, it is very important to take into account the environment and the characteristics of the intervention.

In Latin America, due to the lack of housing, the construction of new housing is common, unlike other countries where interventions are focused on restoring and expanding existing buildings. One of the most frequent mistakes made when restoring is not doing it with the same original technique. For example, in interventions in constructions with earth, the indiscriminate use of cement or any other modern material often accelerates the destruction of the heritage. For this reason, it is essential to remember that earth is restored only with earth. On the contrary, in new constructions it is possible to make a technological mixture of earth with other materials.

Knowing the Soil and How it Behaves

Soil is the product of rock erosion from the earth's crust. It is composed of gravel, sand, silt and clay. The geological profile of the earth's crust is: "horizon 0", traces of vertebrates; "horizon A", dark, organically enriched mineral and in an erosion zone; "horizon e", light, reduced mineral horizon in organisms, with clay, iron and aluminum oxides; "horizon b", oxidized minerals enriched with clay and iron and aluminum oxides and/or organic material, alluvial zone; "horizon c", minerals included in a non-melting sediment, and/or highly decomposed bedrock residues, may be partly oxidized; "horizon z", generally bedrock, less decomposed at greater depth.

With the passage of thousands and thousands of years, the mother rock of planet earth was degraded and eroded by the temperatures, pressure, wind and bacterial agents, causing them to be fractionated into large and visible grains (pebble), smaller (fine and coarse sand), particles not visible, and rounded (silt), until they reach very small fractions of laminar shape that are called clays, these have the power to join and cement the coarser grains. These joints are produced at the molecular level by electrochemical forces and can be easily visualized with the following example: two wet glass beads attract each other, but two wet glass sheets stick together. D; in a similar way, the mixture of soil contains rounded parts (silt and clay) and lamellar parts (clay) when they interact with water.

When building with earth, two elements must be taken into account: density and humidity. The more energy given to the loose soil, the more the soil grains are accommodated, expelling the air that exists between the grains. In some cases, water is also expelled, achieving higher densities that confer greater resistance to the finished product. On the one hand, water is the vehicle that allows the accommodation of the grains of soil, without wet soil, construction with soil would not be possible. On the other hand, once the construction is finished, it must be protected from excess water. A lot of humidity is the enemy of construction with earth, but at the same time, without humidity, construction with earth would not exist. One speaks of ‘water aggression’ when there is more water than necessary.

When working with earth, it is important to take into account its natural moisture, (the liquid part), because it will fill the empty space left by the solid part. Then it is also necessary to ask what degree of humidity you are working with (dry or wet soil). The water used in construction must meet certain requirements; it must not be contaminated and must not contain chemical aggregates (neither very acidic nor very basic). These requirements are normally met in drinking water and rainwater.

There are three tools to keep in mind to know how the earth interacts with itself and with other materials:

1. Understand how the earth works as a three-phase material (solid, liquid and gaseous), with respect to the energy applied to it and the amount of water used, which determine the mechanisms of union of the particles of earth.
2. Identify the composition of the soil (if it is clayey, sandy, silty) and the proportions of each layer (bottle test), to see if it is suitable for the new restoration and/or new construction to be carried out.
3. Choose a construction technique with soil suitable for the intervention (adobe, rammed earth, mixed techniques, etc.). There is a wide range of possibilities of the use of earth that depend, among others, on the quantity of water, local customs, and climatic conditions. In other words, it depends not only on the available land, but also on the conditions of the building site.

In this section we will deal with point 1, leaving points 2 and 3 for the next two sections.

The architect Wilfredo Carazas devised an exercise (called the "Carazas test"), the aim of which is to understand how the different phases of the soil's states (solid, liquid and gaseous) interact depending on the energy given and the amount of water used. Test cubes are made with a certain compaction energy and a certain amount of water. The compaction energies are three: loose with ease, manual tamping with the fingers and with the help of a tamper. As for the quantity of water, there are five grades: dry, wet, plastic, viscous and liquid. This generates a grid table with fifteen situations that combine each of these characteristics. These grids are made into tables with different types of soils (silty, sandy and clayey) to then compare their different behaviors.

The exercise is performed by filling a 15 x 15 cube with the combination of humidity and compaction states mentioned above and making volumetric measurements (density) and the amount of water incorporated (humidity). Based on the data, conclusions are drawn about how the soil grains behave internally. The types of soil used during the trial in Lumbisí have been local clay soil (‘chocoto’) and a mixture of clay soil and fine sand.

Tools

Grill where the exercise will take place

The working group was divided into two teams and each one received as material: a mold, a water meter, a clamp, a basin and a bucket to "assemble" and "disassemble" for each grid: in each position the same amount of soil must be used, which is the amount that corresponds to fill a bucket in a dry and loose state. The first modality was dry, without water; the second, minimally humid (you can make a little ball and do not get your hand wet), the third, plastic (water is incorporated until taking the consistency of mud for pottery), the fourth, viscous (consistency of cream) and, the fifth, liquid (water acting as a vehicle for the earth), which is used for paint and coatings.

As for compaction energy, when the amount of water has occupied the space between the solids, it does not produce any action and neither air nor water can be expelled. What we wanted to measure through this test was the volume of all the parts of the ‘chocoto’ and the mixture, that is, soil, water and air, comparing them, and the difference between the three forms of compaction. By removing the air and displacing the water, it acts as a binder, together with the energy of the hands and the water that compacts the soil in the center.

When the soil is wet, it is easier to compact it with the tamper: there is a minimum amount of water and with this form of compaction, there is the maximum force to remove the air between the earth in the squares. This type of technique is used for the mud wall and the BTC Compressed Earth Blocks (it could be that, the soil used was sandy, because it has the least amount of air possible and the amount of water needed to bind the particles). Plastic earth is useful in the manufacture of adobes and plasters. To obtain the viscous state, clay and water were mixed. This paste is useful for agglomerating other larger aggregates, such as hulls and bits of soil or gravel. In this way, an earth concrete can be made, built by clay that resembles cement paste and sand and stones, which make up the structure of the concrete.

The barbotine (liquid state - slurry) resembles a thick chocolate: this is made by adding a little more water compared to the viscous state, vegetable fibers (straw) can also be soaked in this mixture to make a good insulating material. In this way, the intersections are covered with vegetable fibers that are welded, without leaving space for air, which remains in the middle between fiber and fiber. Straw fiber has a lot of air; if a sufficient amount of liquid soil covers it, but keeping the air in, in each union of fiber with fiber, the air remains in-between the intersections creating resistance to the passage of temperature.

If the type of soil being studied absorbs a lot of water, as it dries and is left without water it produces a difference in volume that causes cracks. In this case, it is not advisable to use for building.

Classifying soils

The most usual tests to identify a soil are those that correspond to the curve that represents the size of its grains (grading curve) and the one that informs about the characteristic of the final part of absorbing more or less water (silt and clay). With this data they are classified into different norms and compared with a series of standard tables.

Within the granulometry we can identify several types of soil, depending on the size of the grain or particle. In this order, there are pebble, gravel, coarse sand, medium sand, fine sand, silt and clay. Coarse granular materials have no cohesive power, but are used as the structure of what we are going to build. Compared with concrete; sand and silt represent stone and sand and clay is the cement.

Soil with silt, if sufficiently adhesive, is useful for rammed earth and large adobes. In addition, if you make a mixture with 15% clay, 20-25% silt and 50-55% well-sifted sand, the soil is suitable for almost all techniques. Depending on the type of soil, a certain percentage of cohesive material can be added. If it is sandy soil, cement can be added (max 10%), although if the environmental impact is taken into account, this is not ecological. If we have clayey soil, lime can be added (15%). Finally, if straw is needed, the 'chocoto' mixed with little sandy soil is perfect for adobe, bahareque and for plastering (adding more sand) and for rammed earth (adding a little coarse pebble or sand, to avoid retractions). If no lime is found in the surrounding area, it can be replaced with chalky soil. Clay, lime and pieces of shell add bulk, while fortified lime protects areas, which may be submitted to 'water aggression'.

Lime is naturally found in stone, where there is a so-called "lime cycle". First, the stone is calcined, producing energy and water evaporation. Second, the stone that remains absorbs the water and releases heat. Then, the paste produced is removed, mixed with sand and plaster is made. Everything is mixed together and with the air, the lime takes up carbon dioxide and then hardens. Over time, this stone degrades and becomes once again, the original stone, limestone.

The Tests

There is a series of tests, called 'Field Tests', which are performed with a minimum infrastructure on the same land where the soil comes from, this gives us an idea of the type of soil we have. Granulometry tests are, first of all, sensory (through the touch and the bite test). For example: coarse sand crunches more, fine sand a little less, silt and clay are pasty and do not crunch. By smell, you can distinguish the type of organic soil you have. For example, if the smell is organic, the soil is for cultivation (although organic soils can also be used for some mixtures - fermented soil). In fact, some brick makers take surface soil which is easier to make bricks, taking the soil from "Horizon B", where organic soil is found.

Sensorial tests to identify the different types of soil

A useful test is the jar (or decantation) test. The method consists in sieving the soil to transform it into powder, mixing it very well with water, shaking the mixture and leaving it to decant. The objective of this test is to establish the percentage of each part that constitutes the mixture, i.e. the percentage of sand, silt and clay. The mixture must be left to settle for several hours, when the demarcation lines stop moving, it will be ready. The lines are created: between the water and the organic part, the dirty water of the clay, the silt and the sand. Through this different granulometries can be seen.

To prepare the mixture:

1. The soil must be sieved to remove the lumps that form spontaneously when the soil is wet,

2. Add this to a jar with water,

3. Add a pinch of salt to speed up the process,

4. The heaviest and thickest part, the sand, will go to the bottom. In the middle, there is a layer of silt and, above, a layer of clay and dirty water. By taking the percentages of each section, one can have an approximate idea of the percentages of coarse and fine soil in the composition.

Another field test consists of a mixture of soil and water, to see how easy it is to make balls. This very simple test, serves to understand how much clay is in the soil. In addition, the hand-washing test establishes if the ground is more sandy or clayey. If you "Wash" your hands with sand, they will be clean, whereas using clay the hands will soapy.

Testing with earth balls

testing with hand washing

When the situation requires it, due to the size of the building site, a laboratory should perform the tests with greater precision. There are three types of laboratory tests:

1. Granulometry, which allows us to distinguish in detail the degrees of thickness of the sand (from the thickest to the finest);
2. The densitometry, which investigates the relationship of the fine material, through the density of the soil. (between humid and dry weight of the soil)

3. The Atterberg limits, which measure the capacity of absorption of water from the fine part of the soil through the plasticity index.

For the granulometry test, a sieve tower is used (a kind of strainer that can identify the thickness of the different grains). From there the curve graph is created, according to the percentage of material retained in each sieve. The material that passes the 200th sieve is the one that corresponds to the silt and clay (fine material).

Densitometry tests consist of decanting the finer part of the soil and measuring their densities: according to set tables the percentage of silt and clay of the tested material is shown.

The Atterberg tests are carried out with the fine material, a technique in which a sample is prepared by making a small chorizo (3 mm in diameter) and its humidity measured. A sample is then prepared with the amount of humidity necessary for a given crack to be closed using a standardized apparatus. The difference in humidity then results in a plasticity index of the sample's expansion and retraction activities. This laboratory test is used to determine the amount of water in the material to be used, to compare soils or different mixtures, to see how plasticity changes, and to establish the amount of clay and sand present.

Bio-construction Techniques with Soil

The techniques of bioconstruction with earth vary according to each region and depend very much on the type of soil existing in the region, the cultural patterns, the climate and the historical reclamation. It also influences the intervention of the state, encouraging or discouraging the use of natural construction, through regulations, laws and facilitation of loans for this type of building. Combining construction with earth and traditional techniques is possible. In fact, in the past, in the bathroom or kitchen tadelakt was used. Today, coating, tiles or other systems are used, and, to support tiles a metallic mesh is placed, then covered with a mixture of sand and lime mortar, and, on top of this the tile is placed.

To different types of soils, different techniques are used. In fact, in order to know which is the best soil for a certain type of construction with earth, it is important to bear in mind that if a soil has less than 40% sand, it is useful to make plaster; if its composition is between 40 and 50% sand, it is advisable for the bahareque and, if it is between 50 and 60% sand, it is used for adobe. To make bahareque, a lot of clay is needed to improve the adherence with the wood or the cane, and also for the plaster. Coarse grain sand, is needed to prepare the rammed earth, and about 17% water has to be added, paying attention to the sound when tamping and compacting the soil.

The rammed earth technique is made with soil that contains adequate proportions of sand and clay, with a low quantity of humidity and is intensely tamped to remove the air. In Spain, the Arabs, and later the

Spaniards, did good works in rammed earth. La Alhambra was built of rammed earth, with some details of adobe, the fountain in tadelakt, earth and lime and many bas-reliefs. In Peru, a good technique of rammed earth was used a lot although, today, it is preferred to use concrete to make the coating. In addition, in Australia and New Zealand, rammed earth production is industrial (pneumatic rammers) and straw is incorporated to make a more insulating wall and with less density. To make it, a dry mixture is prepared and fine straw is added (different from the straw soaked in barbotine).

Our team used 4 parts of earth and 1 of clay for the rammed earth mixture. During the Carazas test, the team could see that the compaction was better with sand in the mix. The ideal is for the base of the rammed earth to be flat in order to apply pressure. The rammer can be 8 or 12 cm wide and the diameter has to be half the size of the width.

The mold

ramming the prepared earth

Preparing the mold for the rammed earth

rammed earth example

Adobe is an ancient technique that is still used today. The adobe is a parallelepiped element, molded when the mixture of earth and water acquires a plastic state. All types of construction with earth are often called "adobes", but this is not correct. Adobe is an artisan production: it is used as a load-bearing wall and therefore precautions must be taken in seismic zones, keeping the relation between the width and height of the wall. Adobe is a mixture of mud, very clayey earth and vegetable fibers added in great quantities. The latter are the structural elements, as they resist traction in the event of the rupture of the element, which have approximate dimensions of 40x20x10. Since the mixtures are in a plastic state, a medium compaction is required. Cracks occur in the manufacture of adobe, coarse and fine grain (volumetric difference) is interleaved to prevent shrinkage. In order to improve the cracking, sand is used to minimise the size of the cracks. In adobe there is also movement of water towards the outside. Adobe dries in the sun, in extreme climates, it is necessary to cover it, whereas in humid climates it endures more time. The adobe needs to be turned over and left it stand for 15, 20 or 30 days, depending on the climate.

A common practice in the countryside is the addition of cow or horse manure; the soil is left to rest for three days to a week, then bits of straw are incorporated and used as a seam in the cracks. With this chemical process, the clay flakes are opened and are left much more plastic, improving the adherence of the mixture. The mixture obtained is more workable to make adobe. The rotting mix can also be made with vegetable fibers. The working group used cut straw in the mix, it is possible to add long or short fiber straw. it is said that the straw "sews" (i.e. unites) the mixture. The earth is compressed and the straw tractions, where there is a crack, the straw prevents the parts from separating. In arid places or where it is not local custom to use straw, other vegetable fibers can be used: In Mexico, agave and aloe vera fibers are used. All fibers that can be cut to be between 1 and 1.5 of 1 cm are suitable to be incorporated into the mixture. To leave straw overnight, it is advisable to cover it with mud, so that no microorganisms can ruin it.

Unfired brick is another technique. It is a mixture similar to that of adobe, but which has much less proportion of straw and, which is not added a posteriori as in adobe. In order to prepare this type of brick, vegetable fibers and cow dung are also used so that it rots. There are some differences between adobe and brick: for adobe you need a lot of straw, (not for brick), because adobe is bigger than brick; an adobe wall maintains better the constancy of the constant humidity of the environment. In fact, adobe maintains more or less 50% humidity and the construction can "breathe", absorbing and unabsorbing water. The unfired brick, as well as the adobe, has to be protected from the aggression of rainwater and / or outside.

Another constructive technique is the Compressed Earth Block (BTC). It is built with a press that can be manual or automated and that, by compression, densifies the mixture taking out the interstitial air and uses very little quantity of water for manufacture. The original press and the most widespread is the "Cinva-Ram", of Colombian origin, but has become popular throughout the world and is currently manufactured in different shapes and fits, according to the press used. When the presses are manual, they have different mechanisms that allow with the same movement of the lever to compress the mixture in a box and then to push the BTC to remove it. The BTC has a very regular dimensions and provides a more uniform product than adobe and as a result, walls are quite similar to other modern techniques.

Another technique is COB construction. COB is an element that is worked as a ball of mud and straw and then placed directly on the wall, without intermediation between preparation and placement. Exterior walls are leveled with a paddle to smooth down the flat exterior surfaces.

Baharque is a mixed technique (using clay and a load-bearing structure of another material), it is prepared by adding long straw, clay and is then coiled/mixed into a wooden or metal structure. According to the place where it is made, it has a different name (for example, quincha, fajina, etc.). In Ecuador, it is called baharque, and it is a wooden structure with some wooden rods, placed separately so that the clay mass with long straw can stick to it.

The bahareque can be partly prefabricated, making the load-bearing structures in the workshop, and then taken to the building site, connected and then embedded with the mud mixture. For example, there is a construction system in Chile that uses metal; it is anti-seismic, its structure is made of iron and it is plastered with the mud mixture (metallic quincha). If the iron is well coated, there are no oxidation problems such as those that occur when wood is used, or fungi or bacteria risks. In Argentina, the structure is made of wood and the so-called "enchorizado" is used, which is a bundle of straw in the form of "chorizo", plastered in mud. It looks like a high wire fence. In fact, there is wire every 40/50 cm. The straw is left long and embedded in mud, twisted and laid to create the shape of an "8" with one/two wires. By making an "8" below and above, a wall is created which is then usually plastered.

To fill the space in the middle of the two layers of a bahareque there are many options. You can make one or two layers (double mesh). In the case of a single layer, the center of a framework of bamboo rods is assembled, this is used above all for interior walls, as they do not need so much thickness, thermal or acoustic insulation. straw soaked in barbotine is prepared with long straw soaked in a slurry, this serves as a filler in a wooden structure such as the bahareque and the thermal insulator: (it does not constitute a structural part).

Bagged earth, misnamed "superadobe" is a tube of earth that is placed in a container bag and then tamped down. Its shape is organic and it is a fairly new technique, which is used in emergency situations. Its main disadvantage is that it is a very labor-intensive technique, especially in the upper stretches, since it requires intensive labor and, if a correct coating was not made to protect against weathering, it can be substantially damaged. There is a coating of Arabic origin called tadelackt, it consists of a series of steps to make a plaster with the addition of lime, which leaves a finish similar to a smooth and waterproof stone.

With regard to the calculation of load-bearing capacity, the knowledge of statics used for other materials and techniques should be used, since earth behaves like any other building material (its particular characteristics should be taken into account). One of the characteristics of all constructions with earth is the drying time: (our team has built on a site with a lot of water, which has to still come out of the construction). For constructions with earth, it is important to stick wet against wet. If there is a dry part, it absorbs the water from the wet part and a fracture is formed when it dries, each construction has a different drying time.

Parts of a Building: the Foundation

The foundation is an item that is always present, whatever the type of technique. Although it depends, in part, of the technique to use, the most suitable choice is determined by the type of land of the building site and the local material that is available. In some regions where there are no stones, concrete is used. In the case of stones, a base is built by joining the stones with a mortar. A good advice is to see how the foundations were historically made in the region. It is also important to take into account the stem wall that protects the wall from splashing surface water or rain.

In the case of the experience in Lumbisí, the foundations are on rocks correctly arranged to receive the rammed earth: a foundation with a minimum height of 60 cm was made, a smooth foundation such as for the basis of a house needs to use mortar. The first layer is made of stone and earth. The earth is placed by hand between the stones so that it can be tamped down more easily.

The Plaster

Another area that is quite independent of the construction technique for erecting walls is plaster. Coating (or plaster):

- It covers cracks.

- It has to be an intermediate mixture between the liquid and pasty state, to be able to work with a with trowel.

- It can be done with a machine and projected.

- It can be used to cover adobe, quincha, rammed earth, support and concrete.

- It is made from approximately 1 cm to 1.5 cm.

It is not a problem if the support of the plaster has granules. For all the finishing results (plaster) 3 layers are recommended: a thick one, which compensates for the difference in level; a thin one, which consists of a small one fine layer of sand and clay with chopped straw, it almost does not crack and to make it you need to moisten it by removing loose grit with a sponge (for example using a credit card) and then you can pass a layer of paint (wet on wet) If you use lime and marble, the plaster is stuccoed (smooth and glossy). The use of lime for terminations is recommended. 'La cementina' is a modified lime with some additives.

THE MIXTURES

To test which mix to use, samples are made with different dosages. For this work it takes a few days for the samples to dry; but because during the workshop there was not much time, we could observe 3 characteristics of each formula:

- Resistance,

- Thickness,

- Presence/absence of cracks/shrinkage

Preparation of different doses for choosing the adequate mixture

The plaster of the adobe construction in Lumbisí has been made of two layers: a thick covering, a thin one and the final decoration. To prepare the plaster, the team has created four mixtures in two groups, to be able to choose the most resistant. The technical steps that must not be ignored to make a coating are:

1. See how plastering is done on the site (materials available, local techniques).
2. Preferences and personal needs.

3. Workability.

The mixtures used are composed of:

1. 1 Part of dark earth, 1 part of fine sand and water.

2. 1 Part light earth, 1 part dark earth, 1 part sand and water.

3. 1 part clay soil, 1 part fine sand and water.

4. 1 part black earth, 2 parts fine sand and water.

Of the 4 mixes, the best for plastering has to shrink, crack little and be strong. The team noticed that mixture 1 had a good appearance and small cracks. No. 2, with more clay, had retracted and cracked. No. 3 had a good appearance and No. 4 was not very resistant, breaking easily. To test the mixture without knowing what type of sand it was, the team plastered a wall of squares of 50x50 cm following an inductive learning methodology.

After having chosen the mixture, the team sifted the earth, creating a paste between viscous and plastic states (barbotine) and began to put it on the wall with the trowel: in some places for an aesthetic issue, one can find and use earth of different colors, once the plaster is done, incisions, over-reliefs, bas-reliefs, incrusting little stones can be added. It must kept in mind that earth is easy to work, while the stone and lime are more difficult.

The steps that our team followed and that are generally used for plaster are: preparation of the mixture, incorporation of colour and decorative elements.

Preparing the mixture for the plastering

The first part of plastering is the preparation of the surface. Before starting to plaster, it is important to prepare the surface of the material. The surface of our equipment was earth: (this can be dry or almost dry - (like the bench that our team made) or wet - (like the bahareque). For each surface, the rule is that the surface has to be dust-free and wet. Using a sponge and hands, our team cleaned the surface of the bench and then moistened and smoothed it, removing the air. The bahareque was quite humid, so there was no need to humidify it. On the other hand, the wall had to be humidified and smoothed by removing all the air to make it more resistant. All the concave parts have to be smoothed to remove the air. By removing the air, you reach the point or state of leather, this is the moment reached when the material is wet but without water. For the bahareque, the team prepared the soil with a good consistency so that Don Virgilio could use a spoon to finalise it.

To work an irregular wall, you should use a masonry trowel. The adobe wall is a little easier to make, because it is straight, it is advisable to make it in 3 layers. The first is the wall that acts as a structural support, from which all the dust must be removed and it is moistened (there must be a thick plaster, with straw, with a maximum thickness of 1 cm); the second, thinner, of 5 mm; and, the third is a coating that gives colour, aesthetics and protection (wall, paste with pigment).

Our team used something similar to the "jabelga" technique, which in ancient times was widely used. This is a whitewash, painted with lime, to which marmolina (marble powder) is added. It has an impermeable property and with this you can make both paint and finish, giving a little thickness at the same time. Our team used a bucket, filled half of lime (cementina), and another part of marble dust and by adding water until obtaining a consistency of paint.

Insulation

As for thermal insulation, a material can be insulating if it has air confined inside, generating a low thermal conductivity (in Quito an adobe wall 40 cm thick is used, which is enough for winter and summer). In earth constructions, thermal insulation and an efficient technique must be taken into consideration (for the bahareque it is to fill the walls with straw soaked in barbotine).

On the other hand, for sonic insulation there are two techniques. The simplest and most direct rule is to use a lot of mass to absorb sound energy and not let it pass, because more mass takes up more space. In the second alternative, it is recommended to use layers of different materials, which absorb different lengths of sound waves. With little thickness, but several layers, the same result can be obtained from a great mass (the light material absorbs different wavelengths and the heavy others). For example, to insulate a bay wall using a thin mass, several layers of plaster are used and each layer will absorb one wavelength. For thermal insulation, straw 'Alivianada' with adobe, or straw soaked in barbotine (in this case the plaster has to be light) can be used.

The Constructions made by Our Team

In Lumbisí, the team worked with 2 very different types of sand: coarse, the maximum degree would be that of the pebble (found in a mountain of stone), and fine: (with a sifter you can classify the size of sand available to see what percentages of coarse and fine is available).

The group had at its disposal three types of sand and soil: one organic, one sandy and one intermediate: as explained above, when experimenting with the soil you have to do tests to understand what materials are involved and what techniques can be used. With these soils, among others, a bahareque structure was been built: the vertical part supports the load and the horizontal part supports the mud. In order to prepare the bahareque bamboo rods were fixed with wires. The materials used have been the thick cane, the nail and the wire.

Sharing opinions

constructing the bahareque

Because of the local culture, the frame was been made in the Lumbisi way, i.e., horizontal, with a straight uncrossed mud. To do so, the participants of the workshop have placed the rods horizontally on both sides, this is unlike other places where it is done only on one side, or crossed at 45 degrees. In each country, there is a different tradition, the bahareque-quincha is based on a resistant wooden structure, which can also be of another material, with wooden sticks to support the embedded mud. In general lightened straw (straw soaked in barbotine) can be used, with very liquid mud as insulation in the center of the two layers.

Structure ready to receive the mixture

details of the bamboo support

In addition, a lintel has to be made that joins all the verticals, completing the wooden framework. The amount of straw used in the bahareque is similar to the amount of adobe. The Bahareque in the Lumbisí style is a 2-layer bamboo rod bahareque with a horizontal mud support. Before covering with mud, Don Virgilio filled the center and then the team covered the two outer layers. Because the structure was intended to be made high, the work was shared in two stages, starting at the bottom and covering the mud plastering to the middle and then from the top to the middle. For the mud plastering, lightened earth was used (which is straw soaked in barbotine - the viscous to liquid state of the glove test) and resembles a thermal insulation structure, different from earth concrete. Following the Carazas test, the barbotine allows an aggregate (gravel, brick, hull or in this case straw) to be incorporated. In this way, the water fills the whole space, as in the situation of the mortar which our team removed the air from the earth. The outer mud plastering has been denser than the inner mud plastering, but any type of mud plastering can be used and a coating was prepared for the sound insulation.

As for the wall structure, one of the problems is its monolithic nature, which causes a little retraction and fissures (unlike adobe, where the elements used are small and are placed to create a large element). In order to prevent, for example, a 3-metre long wall from being retracted and cracked, brick or adobe can be placed. Everything comes together and the cracks do not continue to form. There may be a crack between the bricks, but together, this can be accommodated by changing places (this technique is actually called "cutting the cracks").

Adobes

Bench made from Adobe

To make the adobe armchair, Don Virgilio used a mixture of earth with water and uncooked brick, as if they were blocks or fired brick. This traditional masonry technique is also used for common brick. The top layer has to be horizontal measured with the level, so that the result is not an inclined construction, but completely vertical. On all sides of the adobe there is a joint that serves to glue adobe with adobe and absorb the difference that may exist between one piece and another. Each joint will not match, because they will always be stuck. The insulating layer of the house in Lumbisí built by Don Virgilio, stone was used as a foundation, preventing the passage of water by capillarity.

Bio-construction Experience in France: the Story of a Participant

The bioconstruction workshop had as one of its main objectives, the sharing of experiences. For this reason, many times the participants explained and shared their practicesPaola Melosu, regional delegate of the French association Solidarités Jeunesses, explained and showed how and what materials she used to build her house.

Giving practical explanations

The house, built by Paola and a group of friends, is made of straw and wood. Because of its natural composition, each house like this always has to be separated from the ground by at least 20 cm. Above the perimeter of the base, she and her team layeda sheet of tar to insulate the structure from moisture. The house was assembled with wood every 90 cm so that, between each post, bales of straw could be placed. Generally, for this type of bio-construction, the straw has to be very dry and, for this reason, a straw with less than 10% humidity was used. To prepare it, the straw was compressed and cut 93 cm long by 35 cm deep and 45 cm high. A technique to cut it very fine is by using a barrel: you put straw inside and use pruning shears. To press three levels of straw bales are used, (two wooden rods below, two above), after they pressed, pressure needs to be maintained, the compression of the straw bale is fundamental (with wood or metal). However, in a stony area this is not a recommended technique.

Once the straw bales have been placed one on top of the other, between each one a horizontal wooden stick is placed, nailed to the verticals that compress them, in this way the weight of the ones above does not compress the first one and stabilizes the structure. The straw on the outside is covered with a plastic muddy mix so that the lime can stick well.

In addition, the preparation of the mix consists of lime paste, coarse sand and a lot of water. Once ready a machine was used to project the paste. After three to four days, Paola's team put in another layer of lime, fine sand and water, but less liquid. After 6 months, the third layer was added with very fine sand and lime, sprayed again. If you want, you can color the wall or leave it with its natural color. In the interior, thinner walls were made, using the same paste of the first and second layer of the exterior, obtaining in the end a soil with pigments and small pieces of straw and water (without sand). The mixture was only used to cover the vertical wooden sticks.

Showing the technique used in the house construction

To insulate, the group created a 50 cm glass foam and, for the roof, a cellulose (recycled paper paste). The roof is made of tiles and, inside, there is a BTC Compressed Earth Blocks wall behind the chimney. In addition, a stone staircase and the floor with earthen tiles were used. For the parts most exposed to the rain, a wooden protection was added and the roof was designed to protect the walls.

If you want to decorate the earthen walls inside the house, it is possible to do so and you have to prepare them with a brush and sponge to remove all the dust and then use a sprinkler.

THE ECUADORIAN EXPERIENCE: THE WORK OF ENGINEER PATRICIO

Professor and engineer Patricio Cevallos showed the team many of his buildings in Ecuador, explaining for example that, on the coast, the traditional construction is with bamboo. For this reason, chopped cane (open bamboo) is used. For example, to build a cozy house with pillars of mango trunk, diagonal columns have been used to support earthquakes and in the kitchen a floor of chopped cane. In the south of the country, on the other hand, for example, in the border area of Peru and, in particular, in Vilcabamba, the bahareque is used. Engineer Patricio also built a round house for a shaman in the Sierra, but with another type of bahareque that is a little more urban and built with wood and cane.

In a seismic zone such as Ecuador, adobe and rammed earth are also used. The "hand-made wall" was considered a solely Ecuadorian technique, but the University of Peru has discovered that it was also used in ancient constructions of the Incas and, today, it is used more for enclosures. The wall is built according to a system of cells, placed one next to the other, similar to the COB, but without a mold. Research has not yet been done on these centennial houses, but the Patricio is asking the University of Ibarra to make them, because the texture is very different from the rammed earth and adobe, in Lima, for example, it was built with guayaquil cane, which is typical of Ecuador.

Another project in which Engineer Patricio has taken part is "Con lo que hay" (reference: http://ensusitioarq.com/con-lo-q-hay.html), an architecture workshop during which a team has worked for a year for the garbage recyclers, building a site to protect the workers from the sun and rain. He made a wall with tires, wood and cane, and the floor with straw, earth and lime, because it is very resistant. A similar example refers to the plaster mixture of our equipment, composed of clay, lime and straw: lime is used against moisture and straw brings it all together. Patricio also told us about a project for a village that lives inside the Pululahua volcano. The materials used have been wood and earth as thermal and acoustic insulation.

Patricio shared, about the seismic history of Ecuador. In particular, that Lumbisí is in one of the areas with the highest seismic risk in the country. In Manabí, a place on the Ecuadorian coast, in 2016, there was an earthquake in 2016 of magnitude 7.8, the most destructive since 1987. There, the engineer followed a community project for a university campus of 12 thousand square meters, built of cane and mud walls. Always for this reason, Patricio works a lot on the antiseismic argument, because the use of a material is not synonymous with security. In this sense, he is investigating the resistance of a construction in Bahareque, participating in a research with the Catholic University of Lima. It is a real scale test to test the resistance of a typical Bolivian adobe construction, after a test done in Germany that had confirmed the analysis of its resistance. This simulated an earthquake of magnitude 9. In terms of construction, it was destroyed because in the case of such a strong earthquake, the earth supports compression, but not traction. The test has been done again putting a reinforcement of plastic mesh and thus two movements have been noticed, that is to say, the movement of the earthquake and a horizontal displacement of 25 cm. Thanks to the reinforcement, the construction has remained standing. This test demonstrates that in seismic zones it is fundamental to reinforce.

Four examples of constructions proposed by Patricio have been: a construction with wall and bahareque; one of adobe, wood and brick; another one of concrete and adobe; and the last one of adobe. With our team we visited one of the houses he created the plans for: in Cumbaya. This one needed a framework and, for this reason, packages of 7 adobes have been made pressed laterally by metallic sheets and transfers and has been reinforced vertically and horizontally with lime.

Finally, something that should be taken into account in earthquake zones is that an earthen house is first broken in the corner for this reason; it has to be monolithic, in the form of a "T" or "L". According to the engineer, rammed earth is a little problematic in seismic zones. A BTC Compressed Earth Blocks machine has been used to make the adobe, which produces 3000 adobes per day and with a force of 20 tons.

Bio-construction and energy

In Ecuador it is possible to heat water with solar panels, but photovoltaic is not used because it is very expensive, unlike in Europe. At the moment, photovoltaic panels cannot support the human need for energy. Until today, there is no energy solution other than oil and it seems that the only sustainable solution would be to reduce energy use. In the '50s and '60s, every home consumed much less than it does today. If you produce less, you consume less.

The use of solar panels is becoming popular, however a study that said that within 20 years we would have big problems because of the enormous amount of garbage produced, which also the panels will contribute to, because we do not know how to recycle them. Another relevant issue is that of costs. The movement of "0 consumption" of energy in a house that uses solar panels, seems inconsistent, because if you put a lot of panels to get energy, these will also be waste one day. One could talk about energy production so that efficient cities are built, reducing energy consumption. In fact, building with earth allows to reduce the need of energy of construction in concrete. In terms of hydroelectric energy, in some cases it works and in others it does not. Graphite, a mineral is being studied, with a sheet of minimum thickness of the carbon particle, totally transparent it has a great capacity to produce electrical energy.

The Green Roof

Bioarchitecture is spoken of when it is built according to the climate, thermal gains, ventilations and the contribution of technology that consumes energy. The green roof is an example of bioarchitecture, but there are several types of green roofs: very expensive, efficient, plastic, not consistent with the idea of bioconstruction. A green roof has a roof as a structure, which can be made of concrete, wood or veneer and which supports what is going to be above. To build it, calculations are made as for a wall: it has to be impermeable, more in places where it rains a lot and less in other drier ones (in Lima, for example, there is never a big downpour). The waterproof layer can be BTC Compressed Earth Blocks, or an asphalt membrane, a synthetic paint, nylon ... Another layer is an anti-root mantle, which depends on the vegetation of the place and prevents the vegetation from breaking the the hydraulic part of the construction.

The green roof returns to nature the space that is "stolen" when it is built. In addition, the roof needs a mantle or water folder to carry rainwater. It can be made of coarse sand, chopped brick or pebble. In a part of Argentina where it rains little, there are mud roofs that absorb water. In addition, the roof needs another layer of filter, which lets the water pass like a sponge, but prevents the entry of the passage of earth of about 10-15 cm. At the edge there is a blanket of stone, a gutter that conducts the water in a blanket-laminating water conduction. If there is a lot of rain, find a geotextile that lets the water pass, but not the earth. The last layer is that of topsoil.

The roof can have many layers of different materials and different types of structures (small, large, very inclined). It has to be inclined from a minimum maximum of 2-3% or can be flat as a terrace, depending on the place. In places where it rains a lot there is the phenomenon of "water retention": it rains and, up to 20 mm, the roof absorbs the water which it returns for the following two days. In France there is, recently, a law that says that you cannot build for a total of ten square meters without green roofs. In Santa Fe, also, 50% of the population must take into account water retention. The green roof is found more in cities, because it is a way of restoring the green space that was removed to build.

The Colonial House in Lumbisí

Our work team has made a visit to some earth houses Lumbisí. The houses visited are made of adobe of about 40 cms thick with a dividing wall, without windows, and very close to the boundary of the land. There is a line where the adobe changes position, inside, there is a ceiling that coincides with the change of position of the brick. This represents the most habitable part of the house, with greater thermal insulation (40 cm long adobe) and protection of water. The entire perimeter of the house has an eave of protection against water. In an adobe the granulometry is important (well granulated earth), using a little fine (clay), a little less fine material, silt, fine sand, coarse sand and pebbles (which is used when the dimension of the pebbles is smaller than that of the brick). It is not possible to put stones in the levelling of plaster, because it ruins it, but it can be used in an element with more bulk such as rammed earth. The dimension of the stone is related to the smaller dimension of the element: If an adobe is big enough, you can add stones. The house we visited had stones added, and only the roof has needed repairs in almost 80 years of life.

In an earthen house the parameters of temperature and humidity are more in tune with those of our body, differently than in a concrete block house.

Follow-up system

A relevant part of the "IVS for Climate Justice" programme is its follow-up system: the representatives of the associations involved in the workshop will be the link between the experience in Lumbisi and the associations and working communities in their countries. To support this passage of knowledge and its implementation in the form of a local project, Professor González, with the coordination and support of CCIVS, will follow at a distance the projects of the associations to allow an implementation of 9 months from 2019.

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