Conservation of Traditional Roof in the Historical Center of Quito

Study of the technical interventions of the municipal program "Put your House in Shape"

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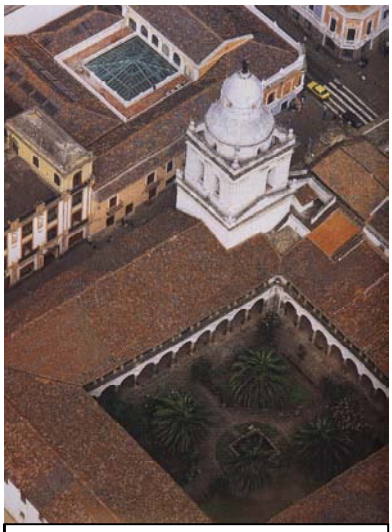


Figure 1: Tower of San Agustín Church and main cloister of the convent. Photo: Jorge Anhalzer

Figure 2: Panoramic view of Quito's Historical Center from El Panecillo hill.

I. Abstract

This document situates the technical problematic related to the conservation of traditional clay tile roofing in the residential architecture of the Quito's Historical Center (QHC) from the analysis of the interventions made by the municipal housing rehabilitation program "Put in your House in Shape" (PHS). The analysis is focused on roof repair and rehabilitation interventions.

Based on field observations, documentary analysis, graphical and photographic documentation and interviews, the report studies the level of conservation of traditional clay tile roof in QHC; it identifies the main traditionally used typologies; the causes and manifestations of deterioration and analyzes the practices of roofing rehabilitation developed by program PHS. The study tries to identify the values and possible improvements in roofing technologies implemented by the program. It will also try to give general technical lineaments to improve the procedures of conservation of traditional clay tile roofing.

II. Introduction

1. Quito: History, landscape and cultural value

Although for many, the particular location of Quito - in a space characterized by extremely steep natural conditions - is incomprehensible, this particular location was the departure point for an extraordinary set of landscaping values, based on the integration between the architecture and its surroundings.

Despite its difficult topography and accessibility, the site had an important character as an ancestral and native establishment; the natural barrier that nearby hills and mountains provided, offered protection of the indigenous rises as much as in front of the strong winds that whipped the region.

The exceptional value of Quito, to be declared the first Cultural Patrimony of the Humanity in 1978, responds to the following

criteria "***(II)*** *to give testimony of a considerable interchange of influences, during a given period or in a certain cultural area, on the development of* ***architecture or technology****, on the monumental arts, on the planning of the cities or* ***creation of landscapes****; and* ***(IV)*** *to offer an eminent example of* ***type of construction*** *or of architectonic or technological set or illustrative landscape of one or several significant periods of human history."*[1]

Figure 3: View of QHC from Avenue Maldonado: in first plane the bridge of "Gallinazos" over the Jerusalem ravine, at the end of perspective, Santo Domingo tower.

Without doubt, the city counts with a unique urban center - architecture and landscape - in the context of the Latin American historical cities. According to what is stated in the text of the Declaration, *"****Quito is the best testimony of the Spanish culture in America,*** *its historical center is the one of greater size,* ***better conserved and authentic*** *and with urban-architectonic monuments, artistic and documentary treasures of singular universal value, that are configuring a set whose* ***architecture is unitary and integrated with the landscape****…"*[2]

Nevertheless, its history and culture goes back to pre-Hispanic times from which, although material vestiges in the site are not preserved where the colonial city was founded and consolidated, the enormous cultural baggage proper to indigenous settlers that marked their footprint in all the material and immaterial dimensions of history: a process of mutual acculturation that influenced the socioeconomic, political and spatial structures of the colonies, giving rise to an accumulation of cultural accomplishments and manifestations that have remained in Quito as witnesses of its history.

Quito's landscape could not be understood, according to Luciano Andrade Marín, without considering *"the latitudinal and altitudinal position of the site where the city, so near the Equinoctial Line is based, and so elevated regarding the sea level, that produces on it an entirely peculiar climatic physiognomy"*

The city-planning dimension expresses the ingenious adaptation to the Andean geography of the European urban model in form of checkerboard – "damero" in Spanish -, applied in century XVI in colonial cities. According to priest Juan de Velasco, the streets were "*traced with a cord and divided in regular frames, with multiple plazas (squares)"*. This primary geometry of urban frame, applied to the irregularity of the topography, produced that many streets, crossing several hills, had to raise and lower their trace, giving to the city aesthetic characteristics of great singularity. The deep ravines that crossed the large city motivated that great part of the buildings had to be sustained on arcades and vaults, mastery constructed by the experienced masons of the city.

Figure 4 y 5: Drawings by Arch. Oswaldo Muñoz Mariño, images of Quito's urban landscape,1985.

[1] Criteria for Quito's inscription in the World Heritage List.

[2] Peñaherrera Andrés, Evolution of the urban layout of Quito from 1500 to 1922, in memory No 2, Journal of the Ecuadorian Society of Historical and Geographic Investigations, Quito 1993.

Figure 6: Roof tradicional system. Hospital San Juan de Dios, 1987.

In addition to such an urban context, **Quito's architecture** constitutes a fusion of forms, materials and techniques of varied origins, times and cultures. The city is distinguished by having construction and religious complexes of great monumental value, which, in perfect harmony with civil works, closely attached to hundreds of residences of academic and popular character; give rise to an exceptional urban landscape where the relation between nature, architecture and man is finely resolved.

Quito's traditional house, heritage of the great Mediterranean civilizations, has one, two or more patios, with the sporadically presence of orchards, surrounded by corridors and galleries, with terraces made to enjoy the splendor of the sun. Fundamental element of this architecture is the **clay tile roof** that marks the image of this particular habitat.

2. The evolution of the clay tile roof in Quito

Figure 7: Skylight. Note the wood structure and "chahuarquero" battens. The soffit is supported by a layer of vegetal fiber made of reed or "chaclla".

The fifth facade is an amalgam of elements: roofing surfaces, patios, backyards, terraces with balustrades: a valuable **cultural landscape** produced by the spontaneity and simplicity than encompasses the sensitivity of Quito's constructors. Scenario characterized by powerful games of light and shadow; with labyrinths of forms and designs that configure a unique and harmonic image of identity.

In their conformation throughout the centuries, the inclined slopes and cover surfaces of Quito's roofing systems have primarily and strongly influenced the urban layout, its location, topography, the proportionality of urban frame. Secondly, the effects are visible in the spatiality of historical constructions: height, number of patios, typologies; functional distribution, etc. Finally, an influence is noticeable in the application of materials and constructive techniques, as well as in the abilities of its craftsmen.

Figure 8: Etching by James Orton, XIX century. Note extended eaves and cornices of Quito's architecture.

A fundamental element of Quito's roof permanence is the conic or Arab ceramic tile[3]: a flexible and aesthetic constructive element; whose form and geometry facilitate the covering; adaptable to any type of support; with a waved texture and color that mark a particular language in the landscape. The variants in the use and disposition of the ceramic tile roof, as well as their thermal adaptability, guarantee an effective mechanism to fight excessive sun or heavy rains, both often present in Quito.

The first house in Quito, with a roof covered by ceramic tiles dates from 1541, from then, the use of ceramic tiles spread quickly with the establishment of "*potters*"[4] *of the villa*, responsible *to make*

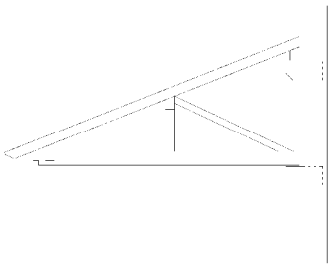
[3] Although their origins go back to the antiquity
[4] Mud workers, makers of roofing clay tiles and abodes

roofing tiles, adobes and other constructive elements in the site of El Tejar."[5]

Very few houses remain from the colonial period; nevertheless these testimonies bring to the present architectonic models, structural and roof systems. Regarding the last one, examples remain that show **ceramic tiles supported in mortar of mud** spread over vegetal fibers -called "chaclla de moyas"-: made out of reed, "suro" (other specie of reed); with supports of "chaguarqueros" (the trunk of blue agave) or other different woods.

See Below figures 9 to 12: Traditional truss typologies. The roof plane resolution goes in one, two or four directions, locally called "aguas"

At the republican period, eucalyptus wood is incorporated for both, roof structure pieces and tilling battens, that serve to support of the ceramic tiles. (See drawings of constructive systems next).



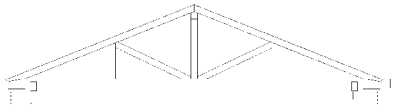
Substantial modifications will affect over the time the great eaves and soffits (see fig. 8) that use to cover the passers-by, eliminated to give passage to the cornices and decorative railings of the republican facades. The arrival of the railroad will mark the use of channels, metallic gutters and other accessories for water collection.

" The fundamental characteristic of the roofs in the buildings of QHC, until the first quarter of century XX, has been ***the massive use of the ceramic tile*** *as the only material to be used for the evacuation of rain water, until the introduction of new conventional materials of industrial production such as the sheet of zinc, glass and, further on, flat slabs of concrete, used since years 40's."*[6]

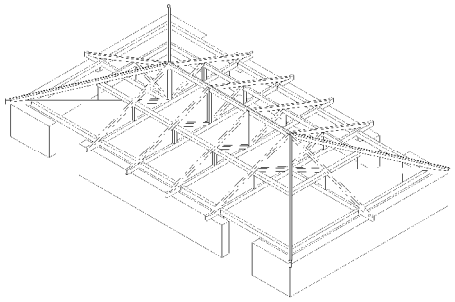
The new materials and constructive systems, symbols of modernity have conspired against the use of the traditional earthen materials and by this, contributing to accelerate the process of substitution of original elements. Starting in the 40's, QHC has been pushed into a constant process of building renovation, often clandestine, with little or no technical criterion, altering its cultural configuration, use and values.

3. Traditional roof systems of QHC

Typologies



The typology massively developed in QHC is the inclined roof covered with clay tile which morphology varies according to the amplitude of the spaces and to the resolution of the sloping. Typologies respond to one, two and four slopes surfaces. In smaller number, flat roofs for terraces can be identified.



[5] Andrade Marín, Luciano; *The first houses of the foundation of Quito 1534* and *Birth of the Quito Hispanic Architecture*, cited in *Fifth Facade* of the Arch. Roberto Andrade and others.

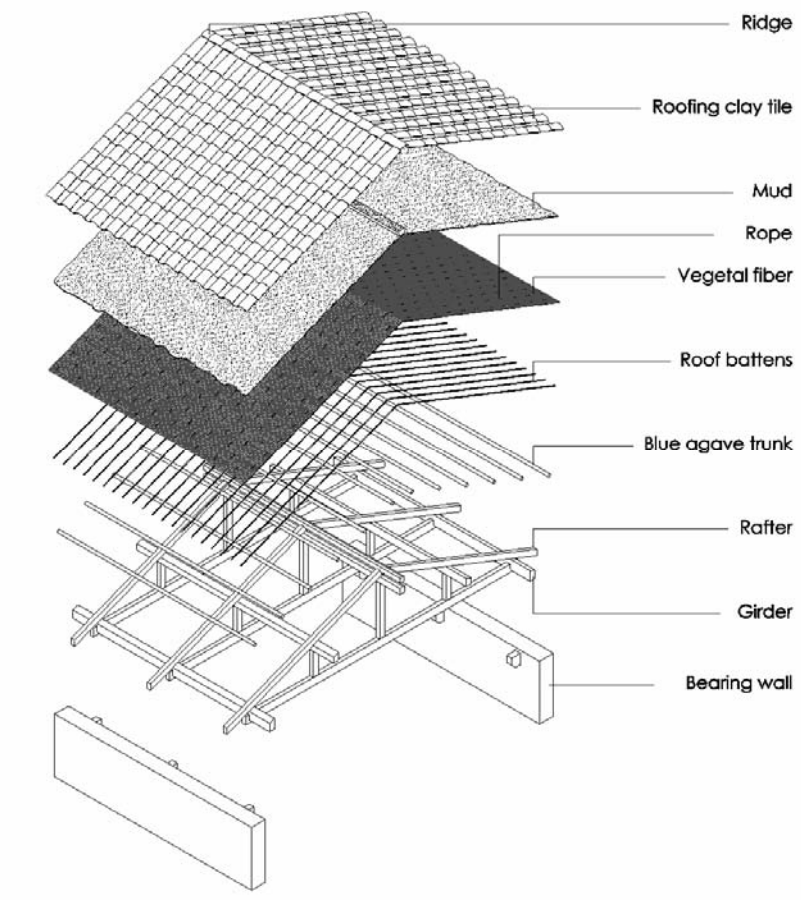
[6] Andrade, Roberto and others, *Cataloguing of the Present State of the Covers in the Central Nucleus of QHC*, Historical, Exempt Study, 2003.

Due to the nature of its structure, the roof system that predominates is constituted by **top chords**, the simplest and most commonly used in domestic architecture. The system, called “pares” consists in a rhythm of wooden top chords placed in oblique way on lateral bearing walls; the top chords are united in the center of the spam through a ridge beam that runs perpendicularly to them. A **bottom chord** run along the lower side between supports, it is a wood piece that saves the distance between the walls.

Roofs composed by **truss structures** are more elaborated and rigid; they can be very complex; predominantly used in great buildings. Such trusses have pieces that work as much to the compression as to the tension and where no pieces work to flexion, they require greater knowledge, dominion of the technique and much precision in the assemblies.

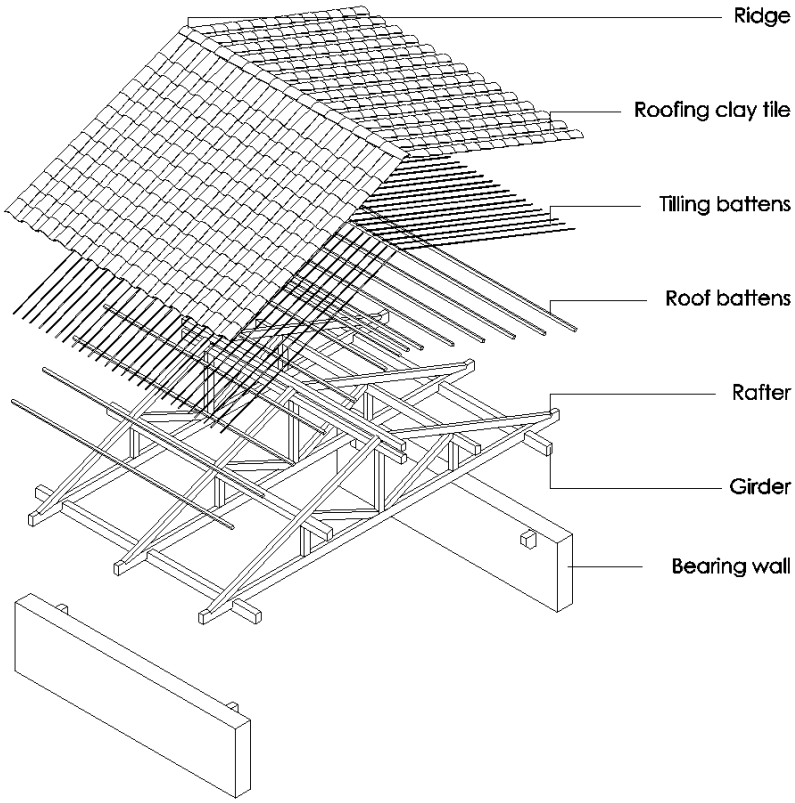
Constructive Systems

Chaclla and Pares



Clay tile on mud mortar supported by vegetal fiber

Tilling battens and Trusses



Clay tiles supported by wooden strips

III. The problem

1. Housing rehabilitation in Quito's Historical Center

Figures 13: "Roofscape" from Manabí Street towards the Basilica. Note roof deterioration in first plane of the image.

With an approximate area of 4 km² and near 5000 inventoried constructions, the historical city of Quito lodge more than 80,000 inhabitants (Municipality of Quito, 2008). From 1987, with the creation of the "Fondo de Salvamento para el Patrimonio Cultural", FONSAL, and the elaboration of the Master Plan for QHC in 1992, the Municipality undertook manifold programs of rehabilitation, mainly co-financed by the I.D.B., other borrowing institutions and agencies of international cooperation.

These investments, that now surpass $125 million dollars, have allowed preserving a considerable part of architectural and urban heritage of Quito. The I.D.B loan programs acted in support of the *"recovery of **monumental area** of QHC with the purpose of seating the minimum conditions necessary to address its process of degradation and to take advantage of its economic and cultural potential"* (I.A.D.B. 822/OC-EC).

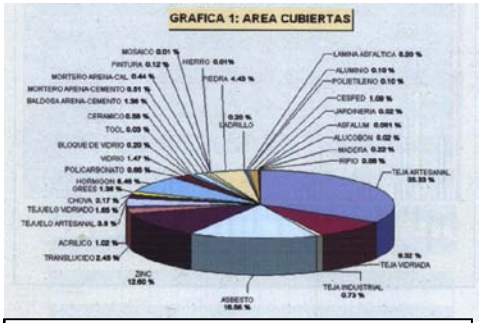
Figures 14: "Roofscape" from Chimborazo street towards el Panecillo Hill. Note intrusion of informal construction at terrace levels.

Although the model of management implemented by Quito has been successfully positioned in the international context, it is evident that deep problems are still unresolved. One of most dramatic, concerns the degraded conditions of **residential heritage** in which the economic, technical and social investments have being scarce and inadequately oriented; considerable resources have been invested to promote the development of housing programs in the historical nucleus, oriented to attract new residents - pertaining to the middle and upper classes - without taking care of the accumulated necessities of popular residents living in deteriorated dwellings, located generally in **marginal historical districts**.

This lack of attention, concomitant to other factors of the socioeconomic dynamics of QHC, has contributed to the degradation of the domestic heritage, massively expressed under the following symptoms:

- Over densified dwellings, socially and environmentally degraded;
- Structures lacking of integrity and vulnerable to earthquakes and other phenomena of natural origin;
- Unhealthy and humid dwellings, vulnerable to fire;
- Historical constructions mutilated by aggressive architectural interventions;
- Ceramic tile roofs in bad state of conservation or squandered by new techniques or informal architectural interventions.

2. Evaluation of the conservation of the traditional tile roof



Figures 15: Pie of covering material in QHC, 2003. Traditional clay tiles represent 33% of used materials for roof covering

A pilot survey cataloguing the state of roof conservation in the central nucleus of QHC was conducted in 2003[7]. The evaluation was effectuated in 34 blocks or "cuadras" where around 400 properties were analyzed. Data collection was appraised trough cataloguing methods that allowed later analysis for determining roof typologies and morphology, the state of conservation. The survey also served to evaluate quantitatively and qualitatively the main materials and pathologies. It also included important proposals for roof rescue and its suitable rehabilitation.

The results of this investigation identified at least 30 types of different roof surface materials inside the monumental nucleus; in this universe, the traditional clay tile only corresponded to 35% while other new materials showed in total elevated percentages: vitrified tile 9%, asbestos 17%, zinc 13%, concrete slab 12%. The figures show that less than half of the samples of the study area conserve the traditional clay tile as a coverage material, without taking into account what materials are used under the tiles as support or what kind of roof structure is used.

[7] Study conducted by a technical team under Arch. Roberto Andrade direction, financed by FONSAL and the Concejo Metropolitano de Quito, as a commemoration study for the 25 years of the Declaration.

A selected sampling, extracted from recent aerial photography analysis, shows the following results:

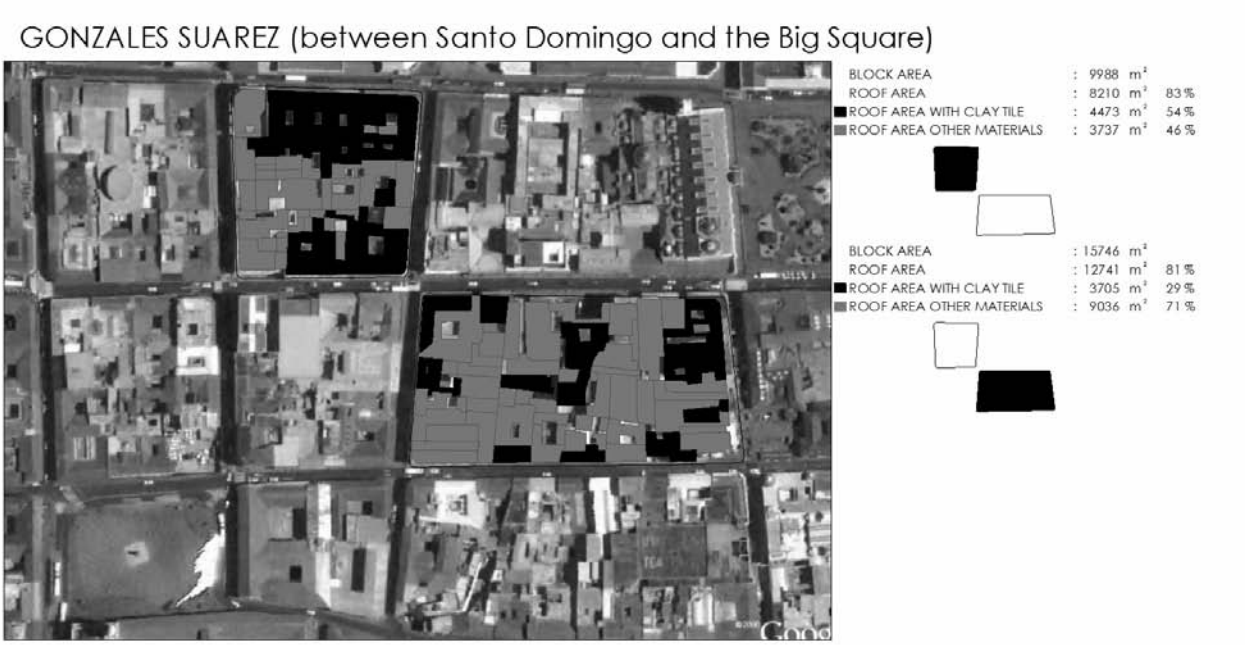


Figure 16: Analysis of tile roofs around Santo Domingo Church, Gonzalez Suarez Parish.

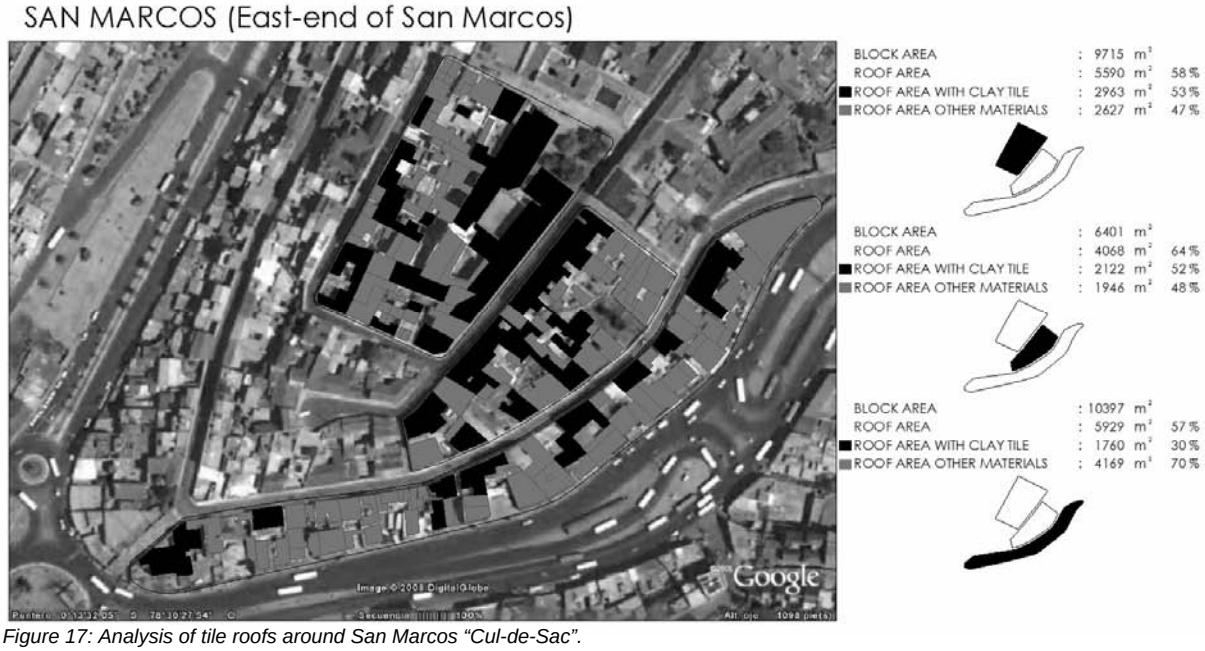


Figure 17: Analysis of tile roofs around San Marcos "Cul-de-Sac".

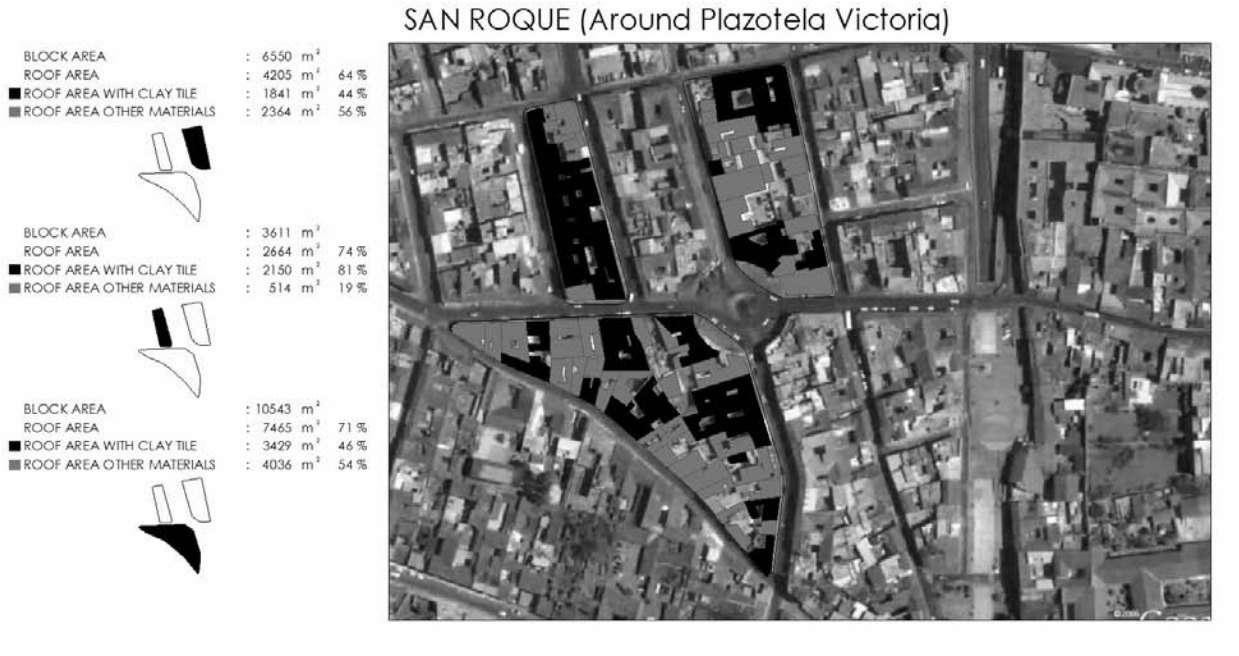


Figure 18: Analysis of tile roofs around La Victoria Plaza

A noticeable substitution of traditional clay tile caused by other materials is advancing both, in the historical nucleon and in surrounding neighborhoods. Such phenomenon is accelerated in locations characterized by an intensified mobility and land use.

3. Factors of destruction of the fifth facade

Figures 18: Traditional typology of roof configuration. Note the unity of the architectural system but also factors of deterioration..

The main causes for the gradual loss of the fifth facade are directly related to the disappearance of three elements that make their existence possible: **original materials**, **traditional techniques** and **abilities** of local craftsmen.

Regarding materials: urban expansion, environmental contamination, lack of quarries or woods reserves, among other factors, make original materials more and more distant to the historical district. Most of the extraction sites are now definitively lost; suitable mud to produce the roofing clay tile, vegetal fibers and necessary wood for the construction of the roofs are now difficulty to obtain and to transport. Furthermore, a decrease of their quality is contradictory accompanied by an increase of their prices, making traditional systems significantly expensive. At parallel, the emergence of new industrialized materials, made of synthetic raw materials, facilitate their use on great scale.

The roofing clay tile, the most symbolic element of the fifth façade, was in recent past a versatile climatic and morphological element; is now being used as a material of formal covering, without a real utilitarian function, and by this, transforming the urban historical landscape into an **unauthentic façadisme**.

In respect to traditional techniques and constructive systems - generally characterized by a slow evolution due to its oral and

practical transmission - the present era of knowledge and information has contributed to reduce their validity and marginalize them through the intromission of "modern" and fluctuating construction forms that rapidly replace traditional technologies.

The present cultural context also contributes to expand a massive and arbitrary use of new techniques and constructive systems made of concrete and steel, which result in aggressive and constant transformation of the historical urban landscape, with loss of its unity and harmony, textures, patina, quality of light and so on.

The **craftsmen**, with their skills and constructive talent- acquired and developed by the continuous understanding and experimentation in the local context- constitute an intangible value, an aggregate imprint to the architecture of Quito. Nevertheless, the different skills related to traditional construction lost their prestige or fell into disuse and gradual disappearance. On the other hand, the new craftsmen force - workers of concrete and steel - new builders and even proprietors, with insufficient architectural formation, are reproducing mechanically and without control, models and techniques without considering the compatibility of materials, their climatic adaptability and functionality, their structural and seismic behavior.

Figures 19: Wood trusses, roof battens and "chaclla" system as support of clay tiles covering.

Figures 20: Similar system than described in previous figure, this time applied in a Galleria. The eaves are cantilevered in both directions and clay tile is supported in a reed mat.

4. Pathologies in roof

Types of Pathologies

Pathologies that can be found in roof coverings, roof structures and other elements of roof construction under the following classification: damages, deteriorations and defects.

*"**Damages** are caused directly by living elements, animal or vegetal, or by natural or physical phenomena such as earthquakes, winds, storms, tornados, rains, eruptions, etc. **Deteriorations** are those that take place due to chemical phenomena. **Defects** are those whose origins come from social practices…affecting the object with technical deficiencies from the very moment of its creation"*[8], that is to say, a bad application of the constructive technique.

Figures 21: Alarming levels of deterioration and introduction of modern materials to patch tiles dissemination.

Types of Affectation

In the roof covering

The most common damages in roof covering materials are breakage, fissures and sliding of clay tiles that cause injurious effects in the constructions due to the passage of humidity towards the structures, ceilings and walls. The deteriorations that appear in clay tiles are exfoliation, in other materials appear in addition oxidation,

[8] Andrade Roberto, *Pathology of old constructions*, in Exempt series No. 5 CHQ: The house. Editorial Fraga, Quito 1991

crystallization and collapses, etc. The defects have to do with inadequate use of slopes and supports, according to the type of the material being used.

Figures 22: This kind of destroyed panorama is more and more often. Tiles become a pathetic vestige among new materials chaotically used.

In the roof structure

The damages found in roof structures have to do with breakage or fractures of the material (caused by xylophages) and due to the excess of load stress, mainly located in stiff elements such as top chords, rafters, roof battens and so on.

The deteriorations have to do with wood cut and sawed inopportunely or due to the contact of these elements with alkaline agents, producing its decomposition, putrefaction, disintegration or xylophage's expansion[9].

The commonest and simultaneously most serious defect in the roof structures is the deficiency of rigidity to resist perpendicular seismic efforts impacting the trusses. Additionally, structures can be found asymmetric, over-dimensioned, with inadequate slopes, incomplete and unstable trusses, incorrect knots, deficient anchorages, etc. Another serious defect that affects to the stability not only of the roof, but also of the entire construction, is the nonexistence of girders and beams that uniformly distribute and transmit the loads of the roof toward the walls.

Figures 23: Ridge, "chaguarquero", wooden chords on adobe walls. Typical damages and deteriorations due to weather exposure and lack of adequate architectural details.

The study of pathologies in the Central Nucleus of the QHC[10], has revealed that the greater amount of **damages** corresponded to breakage and sliding of clay tiles. As far as **deteriorations** were concerned, the deflection and collapses of inclined roof planes predominated due to the fatigue of the material of the structure, lost of ridges and eaves, -mainly affected by the presence of xylophages- and to structural defects. Also, metal oxidation and crystallization of translucent materials were registered.

The major **defects** had to do with deficient or precarious nodes and joining. In addition, a series of disturbances and risky elements was identified in the covers: TV antennas, clothes lines, water tanks, electrical and communication wires were among the predominant examples.

Figures 24: Partial Collapse of roof due to clay sliding, progressive infiltrations and consequent lost of structural integrity. No subsidy or specific intervention is implemented by the Municipality to address this common case of alarming affectation.

IV. Analysis of the Interventions conducted by the Program "Put your House in Shape"

The Municipal Program "Put your House in Shape"

Against this background of vulnerability, characteristic in many of the traditional districts of historical Quito, program PHS is one of the scarce initiatives that have attacked, with an integral approach

[9] Effect of mineralization of organic elements in presence of alkaline components.
[10] Made in 2003 by the team directed by the Arch. Roberto Andrade.

and efficiency, the manifold problematic related to housing conservation.

The PHS is a credit program oriented to proprietors of inventoried constructions, located in historical areas in the Metropolitan District of Quito. The program prioritizes the improvement of habitability conditions and life quality for residents of middle and low incomes and contributes to the conservation of the residential historical legacy, offering comfortable access to credit and manifold complementary advantages:

Figures 25: Roofscape in chaotic process of transformation. New constructions do not often follow regulations and control from city officials.

- 8,000 USD allotted by department (rehabilitation projects admit a distribution going from 4 to 14 departments);
- The annual interest rate is 5% (commercial interest is 12%);
- The term of reimbursement is 10 years, with 2 years of grace;
- The credit includes technical supervision during the stage of design and during the execution of rehabilitation works;
- It facilitates the approval for permissions and licenses of construction;
- The process leads to the declaration of horizontal property, legal statute that allows the sale of the departments.

From its creation in 2003, the program has rehabilitated or improved more than 300 dwelling units, with a particular priority accorded to the following aspects:

- Consolidation and structural reinforcement;
- Implementation of baths and kitchens;
- Space refuncionalization (conversion of big houses into apartments);
- Renovation of electrical and sanitary systems;
- Improvement of patios and waking areas;
- Roof repair and maintenance.

Figures 26: Program tag. 4 apartments are distributed from an single family original house.

Program Methodology

To attain its objectives, the PHS has developed a *social technology* that connects three fundamental actors of the rehabilitation process, through an interactive role distribution for participation and control:

- The **proprietor** of the house (moneylender) participates in the process of rehabilitation having a direct control of the works, he or she has permanent support from the program staff and establishes a flexible relation with the constructor;
- The **constructor** executes the works on the basis of habitability requirements established by the program; he acts accordingly to a budget and under the technical supervision of program officers;
- **Technical staff of the program** elaborate the design for the rehabilitation – taking into account the conditions and potentialities of the construction and the requirements of the client; provide construction permits; supervise the execution of works and are responsible for the progressive payment to the constructor.

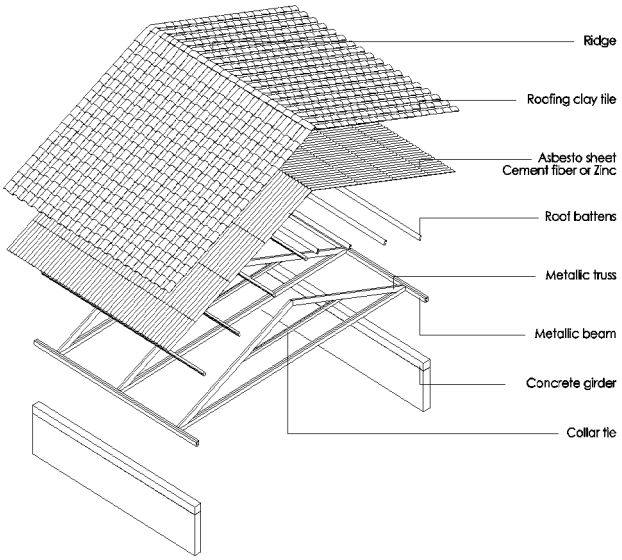
Figures 27: Roof intervention under temporary zinc cover.
Note the utilization of fibrocement sheet as waterproofing layer.

The methodology has allowed reducing the cases of desertion and failure of projects to only 4 cases in all the history of the program. Additionally, the fast execution of works, subjected to a strict timing of 4 to 6 months, allows the proprietors to capitalize the resulting leasing of rehabilitated departments and thus to guarantee the reimbursement of the credit.

Interventions in cover

Within the process of rehabilitation operated by PHS, special attention it is granted to the repair and maintenance of roof. This constructive component, technically delicate and economically onerous, has implied the development of diverse constructive technologies that entail the use of new materials and systems. Such innovations may reduce the costs but inevitably imply the gradual loss in the use of materials and traditional technologies with a consequent reduction of authenticity and cultural values of Quito's built heritage.

Drawings of contemporary roof technologies currently used by PHS:



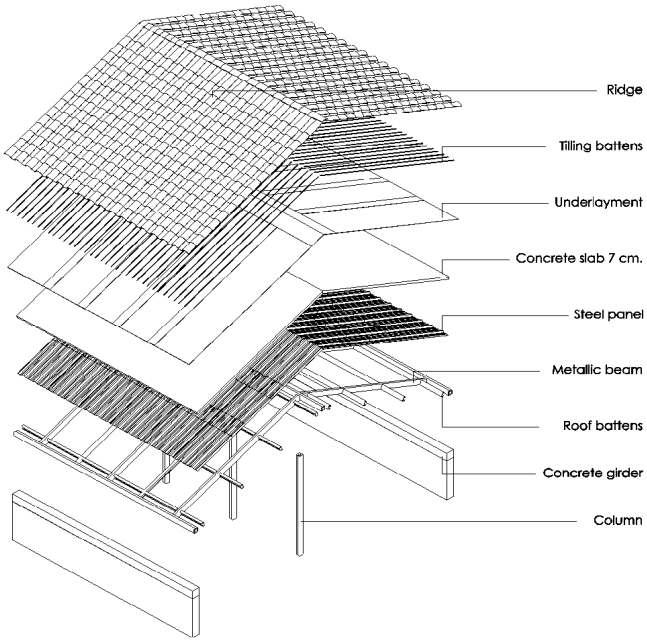
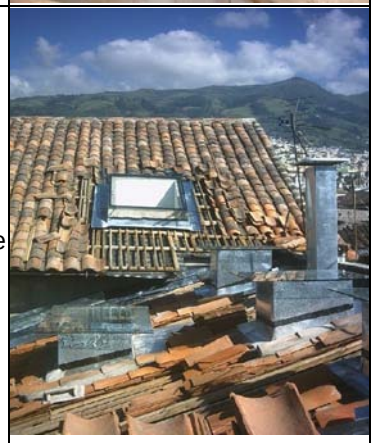


Table 1: Roof interventions conducted by Program "Put your House in Shape"

Type of Intervention	Inventory of used Technologies	% of utilization	Cost average $USD/m2	Advantages	Disadvantages	Images
Repair and Maintenance	Repair and painting of eaves	2.12%	5.49 by meter linear	It reduces the damages and deteriorations It allows to conserve the traditional technology Financial and environmental savings Conservation of the intangible values of the construction Authenticity and integrity of the built cultural heritage	Constant maintenance, Possible annoyances in the daily life	
	Preservation of wood	4.25%	6.00 by Linear meter			
	Replacement of roofing clay tiles and supports	2.12%	17,40			

Rehabilitation	Partial replacement of wood structure and clay tile	2.12%	20,80	Conservation of typologies, constructive systems and traditional materials. Recycling of the materials. Savings of economical and environmental resources	Constant maintenance, Annoyances in the daily life	
	Recuperation of wood structure Waterproofing with geo-membrane. Recuperation of the clay tiles Installation of skylights	4.25%	44,85	Recycling of the materials. Technological improvement of the roof Improvement in the illumination and ventilation of the interior spaces	Possible alterations in the morphology and texture on the fifth façade Non calculated effects of condensation due to geo-membrane	
	Replacement of some structural elements Waterproofing, with asphalt membrane, supported on mats of “totora” (reed), Replacement of tilling battens. Replacement of clay tiles	2.12%	42,50	Recycling of materials Recuperation of vegetal materials as part of the roof system Saving of economic resources	Obligation of periodic maintenance Thermal modification by the positioning of asphalt membrane No calculated effects due to asphalt membrane Labor intensive technology	

Total Substitution	Structure made of Eucalyptus wood Waterproofing with asphalt membrane (chova) on triplex or wooden stave surface. Tiles supported by tilling battens	10.64%	57.13	Typological conservation of the constructive systems and traditional materials	Need periodic maintenance Thermal modification by the positioning of chova	
	Wood structure of treated eucalyptus. Waterproofing with fibrocement sheet Tiles over sheet.	31.91 %	51.10	Low maintenance and durable systems Fast construction Simplified technology that uses industrial materials A lot of suppliers Accessible costs	Potential modifications of slopes may imply modifications in the landscape and generate problems due to inadequate water harvesting. Probable structural problems due to the increase of weight and loads Incompatibility of roof materials with adobe walls Modification of thermal characteristics of the cover: too much heat in day hours and cold in night time When used without tiles covering, it becomes a strange element to the landscape.	
	Structure made of steel: G profiles Waterproofing with fibrocement sheeting Tiles over sheet.	17.02%	49,22			
	Roof structure of steel Waterproofing with zinc sheeting or other metal support Tiles attached to steel mesh.	10.64%	32,25			

	Structure made of steel: G profiles or wood Waterproofing made by using a thin (7cm) reinforced concrete slab (easy slab) Tiles supported by tilling battens anchored to the slab	8.51%		Greater durability Availability of manual labor and materials Does not require maintenance nor periodic repairs	Modification in the volume and slopes of the roof. When used without covering tiles, it becomes a strange element to the landscape. Greater economical investment Disappearance of the traditional techniques Probable structural problems due to the increase of weight and loads Incompatibility between roof materials and adobe walls	
	Roof made of a thin reinforced concrete slab Covering made of tiles supported by tilling battens anchored to the slab	2.12%	81.76			
	Translucent covers of patios and terraces Metallic structure Polycarbonate	2.12%	75	Patios used as living space during all year	Changes in the volume of the building Modification of the microclimate Disfigurement of patio's typologies Modification of the urban historical landscape	

Analysis of the interventions

On a sample of 47 houses, collected between 2004 and 2006 the program has managed to incorporate 156 new dwelling units from which three types of roof interventions have been determined: **8.5%** of interventions involved **repair and maintenance** of one or several elements of the roof. A similar percentage regarded the **rehabilitation** of roofs but **83%** of the constructions implied a **total substitution** of the roof. Such an alarming percentage clearly contributes to an accelerated disappearance of the traditional roofing technologies and to continuous modifications of the fifth facade.

Wood preservation is the most common repair and maintenance operation; roof rehabilitation has privileged **wood and tiles recuperation** conjointly with the introduction of waterproofing layers and **skylights**. In more than 38% of total substitution operations, the constructive system employed **eucalyptus wood structure, fibrocement sheeting and clay tiles covering.** Nonetheless, more than **43%** of roof substitutions used a **steel structure**.

Table 2: roof substitutions technologies

Total roof substitution technologies	% Utilization
-Eucalyptus wood structure -Waterproofing with asphalt membrane supported in a wooden plane, -Clay tiles covering over tilling battens.	12.82
- Eucalyptus treated wood structure -Waterproofing with a fibrocement sheet -Clay tiles installed over the sheet	38.46
-Steel structure with G profiles - Waterproofing with a fibrocement sheet - Clay tiles installed over the sheet	20.51
- Steel structure with G profiles - Waterproofing with zinc sheet or other metal - Clay tiles covering attached to steel mesh	12.82
- Steel structure with G profiles - Waterproofing with a thin concrete slab (easy slab 7cm) - Clay tiles covering attached to wooden tilling battens	10.26
-Reinforced concrete slab -Clay tiles covering attached to wooden tilling battens	2.56
-Steel structure -Polycarbonate sheet	2.56

Table 3: Use of materials in roof construction

Element of cover	Material	% Use
Structure	wood	59.55
	Structural steel	38.29
	Reinforced concrete	10.63
Waterproofing	Asphalt membrane on flat support	17.01
	Fibrocement sheeting	48.93
	Plates zinc or another metal	10.64
Covering	Tiles used in authentic traditional way	10.63
	Tiles used as ornamental covering	87.21
	Translucent materials	2.12

Although the greater tendency is to replace traditional materials by modern ones, the analysis revealed that a preference still exists towards the use of the wood in the roof structure, which could be transformed into an opportunity for the adequate conservation.

One of the fundamental preoccupations for technicians and users is related to waterproofing; the main modalities are the introduction of asphalt lamina and the use of fibrocement sheets. Fast and easy installation -with its consequent financial saving of manual labor- and the perception of greater durability with smaller maintenance are decisive arguments to adhere to these technologies. In this context, the clay tile has stopped being the fundamental element of roof cover. The original functions of clay tile have become simulacra, trying to conserve an identical urban image that has lost in major part it authenticity.

Costs of the covers

The investments for roof rehabilitation within the program reach in average a **36.5% of the total credit amount per house**. Nevertheless the percentual cost of the roof diminishes proportionally to the number of dwelling units obtained after the rehabilitation of the house.

The samples analyzed make clear that roof maintenance and repair is the less expensive intervention, having also environmental advantages and authentic conservation of the heritage. Nevertheless, weak cultural values of proprietors and lack of maintenance practice are detrimental to broader the adoption of this type of intervention.

Type of Intervention	Economical Cost	Cultural cost
Maintenance and Repair	Low cost, aprox. $ 20 /m2	Non existent
Rehabilitation	Middle cost, aprox. $ 45/m2	Low cost. Conservation of constructive systems
Total substitution	High cost. $43 to 82/m2	High cost; lost of authenticity and cultural values

Use of living spaces under the roof

The fundamental functions of roof covers are to offer to a suitable evacuation of rain water and to guarantee thermal and acoustic insulation. Traditional morphology and materials are, in Quito's specific case, practically incompatible with the immediate habitability under the roof. Making space under roof habitable should imply an extreme simplification of cover structures; a remarkable modification of slopes and the introduction of fireproof materials. These conditions may contribute to decline the technological, architectural and landscape values that preservations actions want to conserve.

Regarding the buildings, habitable use of roof could imply substantial modifications in the spatiality and, structurally speaking, addition of weights and loads that can alter the behavior and

resistance of the building. Additionally, other complications may appear through the introduction of infrastructure networks.

Furthermore the existing architectural normative establishes typological protections of roof profiles and skylines. In terms of functionality, the norm limits the use of spaces immediately under the roof to a quite restrictive percentage. The rigidity of local normative is lamentably limited to formal and functional aspects, allowing renovations with scarce technical-constructive parameters and control.

Figures 29: Roof at risk. See the trusses knot system and tilling battens. Dots are indicating xylophage's activity.

V. Discussion and Conclusions

Traditional constructions and - as fundamental part of them - roofs, are historical testimonies that have accumulated signs and values from specific époques and societies. These historical contexts have produce architecture – with its concomitant technical y constructive development- and determined the uses of a space of exceptional value, attributes that make Quito part of the World Heritage List since 1978.

The analyses made throughout the study bring the following conclusions:

- Alarming levels of damage and deterioration in the roofs of the QHC are noticeable,
- Such effects are mainly caused by the lack of maintenance and periodic repair;
- The number of constructive defects is increasing, mainly related to the geometrical resolution of roof structures. Such defect attack to the integrity built heritage, specially the residential one.
- The program PHS has contributed to reinforce a tendency toward the substitution of traditional technologies by modern techniques and materials;
- Within the PHS framework, one of the most important aspects and investment is the roof rehabilitation. Nonetheless, the credit amounts take too much for roof rehabilitation. Therefore, it would be indispensable to establish a separate and additional fund that can contribute to a suitable conservation of roof heritage;
- The actions of roof maintenance, repair and rehabilitation, in spite of being less expensive than substitution ones, are little practiced by program intervntions.
- Finally, it is not technically feasible, nor culturally accepted the habitable use of the spaces under the cover.

Figures 30: Multiples roof damages: replacement of coverings by metal or fibrocement sheets, collapse of traditional clay tile roofs.

VI. Recommendations

General recommendations

- Residential and roof conservation implies to balance the investment between tourism activation initiatives and housing rehabilitation programs. This may imply:
- Diminish the tourist and real estate commercial pressure on the constructions of the CHQ.
- Greater investment of economical and technical resources to the rehabilitation of residential heritage in QHC.
- Implement a special fund for the recuperation and conservation of the fifth facade within the Special Plan for QHC and FONSAL.
- Improvement, organization and renovation of infrastructures in the old city in order to prevent and to mitigate risks, especially coming from fires.

Recommendations for the PSH Program:

Regarding the materials

- To sensitize proprietors, technicians and craftsmen on the economical and environmental advantages involved in rehabilitation practices that prioritize consolidation, reinforcement and the reuse the constructive elements (that still display acceptable conditions of use);
- To economically stimulate the interventions of maintenance, repair and rehabilitation that focuses on preserving and recycling of the original materials.
- To establish regulations that do not focus on formal and inauthentic preservation of architectural typologies but that contribute to the effectively safeguard cultural values.
- To create a “bank of recycled traditional materials” that can be used in housing rehabilitation.

Regarding the constructive techniques and systems

- To document and develop investigations of buildings that still conserve traditional constructive systems of clay tile roofing;
- To preserve traditional typologies that can serve as testimonies and good examples for future interventions.
- To document and to evaluate the interventions in roofs and other elements of the houses, that allow to make detailed analyses and suitable corrections.
- To foment a culture of maintenance and constant repair, through qualification and norm, to create specialized team for the effect.
- To impulse constant investigation for the knowledge of the techniques and new materials that better adapt to the historical constructions, principally applied to covers, and;
- To create incentives for the development of techniques that privileges the conservation of traditional materials and avoids their substitution.

Regarding manual labor and craftsmanship

- To recover specialized craftsmanship in roof production; to identify masons who still have traditional knowledge and practice; to make processes of recovery and transmission of traditional techniques;
- To develop further skills for the existing labor force, through specialized and practical courses.
- To constitute an integrated system of continuous training ascribed to the program in order to connect, inform and train craftsmen, technicians, and proprietors about the best practices of repair, maintenance, rehabilitation and adequate integration of new roof technologies in traditional buildings.

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- *FONSAL: Arch. Juan Carlos Mafla, Technical Director; Arch. Roberto Andrade, consultant.*
- *Multiple masons executing works for the program.*
- Fast appraisal and conversations with proprietors.