Earthen Architecture: Past, Present and Future – Mileto, Vegas, García Soriano & Cristini (Eds)

Knowledge exchange for innovation in the vernacular rammed earth technique, Peru

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ABSTRACT: Vernacular earthen construction in seismic areas of the Andes, the vulnerability of which is compounded by the effects of climate changes, requires the intervention of Academia to develop and transmit innovative technologies that ensure its sustainability. The Centro Tierra research group at Pontificia Universidad Católica del Perú, has developed a project for improvement of the infrastructure of a Colonial hacienda manor currently used as a hotel, of adobe and rammed earth in Tarma and the training of local personnel for strengthening existing buildings and new construction works in rammed earth. Mitigating actions to prevent risks by adapting vernacular rammed earth techniques to innovative anti-seismic and rain-proof aspects are proposed. Findings of the project are reached on the following areas: vernacular and academic knowledge exchange for present-day rammed-earth building, understanding the difficulties in the transmission of new technologies, application of techniques validated in the economic and practical aspects.

1 INTRODUCTION

At present, the vulnerability of vernacular earthen constructions in seismic areas of the intertropical Andean region is compounded by climate changes that are having an effect in the form of rainfall variations and increases, one of the main causes of deterioration of earthen constructions.

Within the context of mitigation processes, the academia emphasizes development and transmission of innovative technology research applied to the safety and sustainability of rural vernacular and heritage earthen housing.

The Peruvian government, through competitive awards of Funds for Innovation, Science and Technology (Fondos para la Innovación, Ciencia y Tecnología), Fincyt, promotes financing projects with the involvement of private enterprises as beneficiaries of research results and participants in the transfer of applied knowledge.

In this context, *Centro Tierra*, jointly with Axis Arte, research groups working at Pontificia Universidad Católica del Perú, have developed and started implementation of a project for improving the infrastructure of the Hacienda Santa María Colonial manor, currently used as a hotel, located in the rural outskirts of the city of Tarma, Department of Junín, Peru (Fig. 1).

Figure 1. Hacienda Santa Maria, view from the patio (Centro Tierra).

For the company, the goal is to improve its financial returns as a result of the renovations to the historic manor and the expansion of its lodging capacity. Innovations are to be applied to earthen construction technology and knowledge exchange and transfer, and seek to train local workmen in structural consolidation and improving the response to moisture of existing constructions, both heritage and otherwise, and in new earthen constructions.

The project leverages this partnership between government, academia and private enterprise to generate investment of public funds in heritage

properties and to transmit and use the results of interventions for conservation of local vernacular architecture, thereby benefitting society as a whole.

The experience will help to test the transfer methodology from the standpoint of repeatability of the proposed innovations.

2 RESEARCH CONTEXT AND FOCUS

The focus of this pilot intervention at the Colonial Hacienda Santa María is specific: it must initially observe current construction techniques used in earthen vernacular architecture in order to meet one of the study's main purposes, which is the development of innovative solutions based on vernacular knowledge.

How can a construction with these characteristics be designed and built taking academic knowledge and experiences as a starting point? The technical team's first approach to local techniques has been through a study of earthen constructions in Tarma and its surrounding area. In general, it was observed that Colonial constructions were made of adobe, while present constructions use the *tapial*, or rammed-earth, method.

In addition to site visits, local master builders were interviewed about existing building techniques.

The use of tapial technology is common in rural areas adjoining the city of Tarma, where the "self-help housing" approach is used. In Peru, self-help housing, referred to as autoconstrucción, is understood as construction by an artisanal builder specializing in the technique to be used in the dwelling—in this case, the tapial method—, who proposes the design of the home. Construction quality will depend on the experience and technical expertise of the builder. The layout and volumes are typical. No professional engineers or architects support the builder in the design.

Constructions, usually homes or homes with commercial spaces, are rectangular and have one or two floors, exceptionally three. The relationship with the topography is essential for the home's orientation which, to avoid steep slopes or land fillings, is longitudinally aligned with contour lines (Fig. 2).

A study of traditional construction techniques allows for validating solutions and, at the same time, detecting a series of omissions and limitations that cause failures and defects in existing constructions. A lack of foundations and stem walls was observed, as well as a lack of collar beams, a construction element that is unknown in the area, among others.

The proposal for the pilot project takes observations into account in order to try to solve and share solutions before onsite validation and validation by users. Note that innovations involve introducing new elements made with the materials used in the project (wood, stones) and that the introduction of new materials is limited to easily accessible and inexpensive materials.

Figure 2. Traditional rammed earth house (Centro Tierra).

No alterations are being made to the *tapial* construction method nor to the basic dimensions of the formwork or mould—the basis for their modular building scale—nor to the earth mixture, which gives solidity to the walls.

3 TECHNOLOGICAL INNOVATION FOR RISK MITIGATION

The city of Tarma is located in the central Andes of Peru, 240 km (150 miles) east of the Peruvian capital, on the eastern slope of the mountain range. It was founded by Spaniards in 1534 in the lower valley, where four ravines meet at 3050 meters (10,000 feet) above sea level. Pre-Hispanic, Colonial and present rural developments are located in the surroundings of the city at higher elevations on steeper slopes. The valley is characterized by agricultural production, particularly floriculture. Due to the layout of the terrain, rural constructions on the slopes receive runoff water, rainwater or irrigation water in the dry season. The city center, located in the depression, receives water both from the surrounding slopes and from the water table which, because of its proximity to the surface, creates serious moisture problems in walls, which have caused the collapse of many historical downtown constructions.

Located in Seismic Zone 2, the area is exposed to local earthquakes. However, since recently there has been little seismic activity, the population does not feel threatened by this phenomenon. How much this factor may prevent transmission of structural reinforcement technologies for buildings remains to be seen.

Hacienda Santa María is the result of at least four construction stages. The initial construction was built in Colonial times (circa 1724), later expanded in 1840 and then in 1900, and the last intervention has been the 2013 pilot project.

It is an adobe house with a gallery consisting of wood columns and balconies organized around two patios connected through a hallway.

The more important spaces like chapel and drawing rooms face the main patio. The manor is built on a slope and its volumes are distributed in one or two levels. The volumes on higher ground are older and are built on terraces made of stone walls and fillers.

The pilot intervention in the section called Los Domingos led to knowledge transfer and exchange. The project consists of building a new volume replacing some storerooms with no historical value and near collapse due to the high humidity of the soil in this area adjacent to the orchard in the lower part of the manor.

Existing volumes were replaced by a new building made using the tapial method at the same location, and maintaining the characteristics of the heritage construction without altering the overall appearance of the home. This decision was made pursuant to the Charter on the Built Vernacular Heritage, ICOMOS, 1999. The new construction also increased lodging capacity by three rooms.

The "Los Domingos" pilot project consisted of an improved tapial construction, innovating the vernacular tapial method with the elements described in Adobe Standard E080 of the National Building Regulations, which has not been disseminated in rural areas and is unknown even to professionals.

Elements new to the Tarma construction context were added, such as collar beams and the connections between the walls and the roof through this beam, and rope ties between collar beams (Figs. 3, 4). The concept of partitions or light structures for non-load bearing divisions in indoor spaces was introduced.

Foundations were reinforced to counter the thrust of the soil and stones were set with a lime mortar that is more resistant to moisture (Fig. 5).

For insulation from soil moisture, indoor floors were built on a filler made up of layers of stones of different sizes. Sidewalks with drains were also built to protect the base of the walls.

The roof structure was calculated in order to determine the center to center distance between beams according to the type and strength of the wood being used. For the roof cover, various layers were carefully installed to ensure insulation and final sealing with a mixture made up of a layer of mud and straw mixture, plastic and properly laid roof tiling.

The sum of new and improved elements enhance the overall performance of the structure against earthquakes, settling and moisture, thereby limiting damages. The above mentioned construction details were developed based on vernacular construction tradition, the knowledge of the master builder, the standard, available materials considerations, and cost.

Figure 3. Introducing collar beams (Centro Tierra).

Figure 4. Connected collar beams (Centro Tierra).

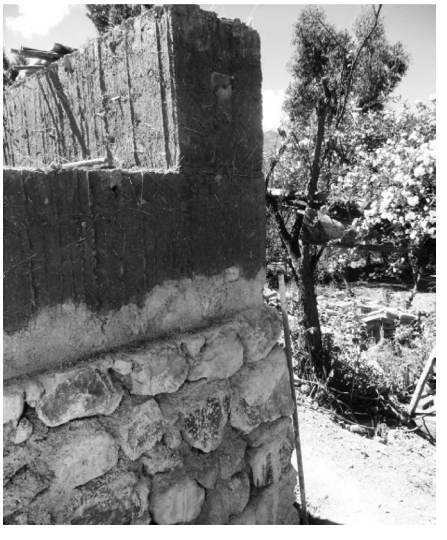

Figure 5. Reinforced foundations with lime mortar (Centro Tierra).

The presence on site of the resident architect provided for instances of discussion and exchange: some construction solutions proposed were rejected and replaced by others. Such was the case of the quincha (mud-covered reed frame) tympanum suggested by the project. This technique is not known in Tarma

and the mason suggested building it with the traditional tapial. The need to reinforce the higher portion of the wall led to installing a slanted collar beam connected by ropes to the horizontal collar beam. This solution is the result of knowledge-sharing between the technical team and the builders.

Reconstruction of the small building provided the possibility of organizing the project in a way that ensured continuous exchanges with local workmen (masons, carpenters) and technological transfer and sharing of results with workmen, local residents, students, professionals and members of the Municipality through a workshop organized at an intermediate stage of the project.

4 METHODOLOGY FOR TECHNOLOGICAL TRANSFER

Repeatability of the proposed solutions is the objective of knowledge transfer during the process.

The choice of workmen (mason, carpenter) is paramount in this type of project. Their knowledge and experience are necessary to contribute and validate construction solutions on site in a continuous exchange with the resident professional. The design was proposed and approved in terms of feasibility and repeatability, while the professional team members, who were ultimately responsible for the project's execution, approached local knowledge with respect and from a research standpoint.

Communication of technical solutions was adapted for better understanding by the workmen and a relationship of trust developed due to the interest in vernacular techniques shown by the professional team members. As a result, tests and prototypes of new elements, such as straw-mud blocks, were made possible.

A workshop for sharing construction experiences was organized at Hacienda Santa María, with the attendance of workmen, interested citizens, students of Pontificia Universidad Católica del Perú (PUCP) and Universidad Católica Sedes Sapientiae—Tarma, municipal officials and local professionals. The workshop had a theoretical component, as well as discussion panels and a demonstration of field tests.

During the sessions, the resident architect/master builder team presented the project. The resident architect explained the technical aspect, while the master builder spoke of the difficulty of executing the new elements, overcoming initial rejection of some elements and his perception of the importance of the improvements. Later, the same information was repeated during a guided visit of the construction. An exhibit was prepared showing traditional and proposed materials, including the historic adobe of the hacienda, adobe forms, good and defective artisanal roof tiles, various types of fibers, and lime and its possible applications.

The exchange portion was the most successful. Each discussion panel included students, workmen, architects, engineers, municipal officials and was directed by one of PUCP's volunteer students, trained as panel coordinators by the Axis Arte architects.

As to information dissemination, a manual in two versions, in booklet and in poster form, has been developed and is currently under review. Their effectiveness will have to be assessed over time.

5 RESULTS AND CONCLUSIONS

Self-esteem is strengthened when theoretical knowledge is validated by professionals and shared on equal terms. One of the insights gained by the technical team as a result of the workshop was the growing interest shown by the population as they valued their own environment and vernacular heritage. However, this initial awareness-raising requires ongoing and sustained follow-up over time.

Among the elements introduced as technical improvements, the collar beam has gained the most acceptance, so much so that the master mason has systematically incorporated it in his subsequent designs. In view of objections from clients who consider this innovation an unnecessary additional expense, the transfer was achieved through an adaptation that he proposed: a half collar beam to adjust to financial requirements.

Results need to be monitored by following up on the activities of the trained master workmen in their future projects. Likewise, in order to aid in building a safe habitat, the academia must assume and meet a commitment to cooperate and provide advice to builders on an ongoing basis.

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