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REVITALIZATION OF THE KICHWA SARAGURO ANCESTRAL WATTLE AND DAUB, ECUADOR: CONSERVATION, ADAPTATION, AND DISSEMINATION OF CONSTRUCTIVE HERITAGE

REVITALIZACIÓN DEL BAHAREQUE ANCESTRAL DEL PUEBLO KICHWA SARAGURO, ECUADOR: CONSERVACIÓN, ADAPTACIÓN Y DIFUSIÓN DEL PATRIMONIO CONSTRUCTIVO

REVITALIZAÇÃO DO BAHAREQUE ANCESTRAL KICHWA SARAGURO, ECUADOR : CONSERVAÇÃO, ADAPTAÇÃO E DIFUSÃO DO PATRIMÔNIO CONSTRUTIVO

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RESUMEN

La construcción con bahareque ha evolucionado con el tiempo, pero hoy enfrenta el riesgo de desaparecer debido a la escasez de materiales, la falta de mano de obra y la preferencia por sistemas "más duraderos y versátiles". Este estudio explora la revitalización del bahareque, técnica constructiva ancestral del pueblo kichwa Saraguro - Ecuador, mediante un enfoque metodológico mixto con varias etapas: análisis de materialidad, diseño, análisis estructural y construcción de un panel de bahareque que integra iconografía andina y se adapta a pórticos contemporáneos de hormigón, metal y madera; desarrollo de un taller práctico para divulgar y evaluar la viabilidad de construcción mediante mingas. Los resultados destacan la viabilidad del bahareque en construcciones actuales, con costo accesible y eficiencia estructural. Se promovió su uso al fomentar la participación comunitaria y la transmisión de conocimientos ancestrales. Es una alternativa para la construcción contemporánea, que preserva la identidad cultural y se adapta a desafíos ambientales.

Palabras clave
arquitectura tradicional, técnica mixta, paneles modulares, participación comunitaria

ABSTRACT

Construction with wattle and daub has evolved over time, but today faces the risk of disappearing due to material scarcity, a lack of labor, and a preference for "more durable and versatile" systems. This study explores the revitalization of wattle and daub, an ancestral construction technique of the Kichwa people of Saraguro, Ecuador, through a multi-stage mixed-methodological approach: material analysis, design, structural analysis, and the construction of a wattle and daub panel that integrates Andean iconography and adapts to contemporary concrete, metal, and wood porticos; and a practical workshop to disseminate and evaluate the feasibility of construction through mingas (communal participation). The results highlight the viability of wattle and daub in contemporary construction, with its affordable cost and structural efficiency. Its use was promoted by encouraging community participation and the transmission of ancestral knowledge. It is an alternative for contemporary construction, preserving cultural identity and adapting to environmental challenges.

Keywords
traditional architecture, mixed construction, modular panels, community participation

RESUMO

A construção Bahareque evoluiu ao longo do tempo, mas hoje corre o risco de desaparecer devido à escassez de materiais, à escassez de mão de obra e à preferência por sistemas "mais duráveis e versáteis". Este estudo explora a revitalização do bahareque, uma técnica de construção ancestral do povo Kichwa de Saraguro - Equador, por meio de uma abordagem metodológica mista com várias etapas: análise de materialidade, projeto, análise estrutural e construção de um painel bahareque que integra a iconografia andina e se adapta aos pórticos contemporâneos de concreto, metal e madeira; Desenvolvimento de workshop prático para disseminar e avaliar a viabilidade da construção por meio de mutirões. Os resultados destacam a viabilidade do bahareque na construção moderna, com custo acessível e eficiência estrutural. Seu uso foi promovido pelo incentivo à participação comunitária e à transmissão de conhecimentos ancestrais. É uma alternativa para a construção contemporânea, preservando a identidade cultural e adaptando-se aos desafios ambientais.

Palavras-chave:
arquitetura tradicional, técnica mista, painéis modulares, participação comunitária

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INTRODUCTION

Approximately 650 to 700 million people worldwide still reside in homes constructed with earthen materials, including adobe, mud, and stone. This represents about one in every 10 or 12 people on the planet. (Marsh & Kulshreshtha, 2021). In Ecuador, according to the population and housing census (National Institute of Statistics and Censuses [INEC], 2022), the use of traditional materials in constructions decreased from 28.7% to 13.3% between censuses held every 10 years; these percentages of housing with natural materials are observed: bahareque (wattle and daub) 5.2%, adobe and tapia (crude bricks) 2.5%, and wood 0.6%. The introduction of new industrialized materials has marginalized traditional construction techniques, such as wattle and daub, replacing them with modern alternatives that alter the cultural landscape and compromise environmental sustainability (Pesántez Pesántez & Tapia Vera, 2018).

The accelerated loss of ancestral construction knowledge, the scarcity of intergenerational transmission, and the decline in the practice of these techniques in communities of indigenous peoples and nationalities have made it difficult to access housing solutions that strengthen their cultural identity and promote sustainability. This phenomenon, prevalent in Ecuador and various regions of Latin America, poses a risk to both tangible and intangible cultural heritage, as well as a challenge to social and environmental resilience (Cordero et al., 2003).

In the Latin American context, research presented at the Ibero-American Seminar of Architecture and Earth Construction (SIACOT, in Spanish) and the reports of the PROTERRA Network have extensively documented the loss of ancestral earth construction techniques and their socio-cultural impact (Cevallos Salas, 2003). In Mexico, recent projects in Oaxaca have promoted the revival and adaptation of wattle and daub, which strengthens the social fabric and improves the energy efficiency of housing (López-Martínez & Torres Garibay, 2023). In Colombia, studies in the department of Cauca integrate traditional techniques with modern construction solutions, which increase the durability and thermal comfort of rural housing made with wattle and daub (Cristancho Barrios, 2024). In Peru, Corrales Blanco et al. (2021) highlight the integration of ancestral knowledge with new technologies to create resilient solutions to extreme weather events. In Bolivia, SIACOT has promoted the valorization of traditional adobe and wattle and daub techniques in projects that reduce environmental impact and preserve cultural heritage (Cordero et al., 2003; Neves et al., 2017).

In Ecuador, studies such as those of Pesántez and Tapia Vera (2018) highlight the value of wattle and daub as a cultural expression, tangible heritage, and sustainable alternative. Likewise, experiences of improving the *bahareque* or wattle and daub technique have been developed, such as the modular panels proposed by Vacacela Albuja and Astudillo Cordero (2015), evidencing a growing interest in adapting the ancestral technique to contemporary construction models. This situation reflects a generalized trend in Latin America, where the abandonment of ancestral techniques has marginalized collective knowledge essential for the habitat (Cordero et al., 2003).

The architecture of the original peoples reflects an expression and relationship between ancestral knowledge and the natural environment. In the case of the Kichwa Saraguro people of the province of Loja, in southern Ecuador, their traditional construction system, known as *bahareque*, has evolved in response to the region's environmental and cultural variations. It is a technique that promotes community participation and is based on principles of reciprocity fundamental to collective life (Corrales Blanco et al., 2021).

These practices have been passed down through generations, often through collective work or communal gatherings known as *mingas*. However, globalization has limited the continuity of knowledge transmission, leading to a decline in its practice. Revitalizing these processes is essential to address housing problems in communities of indigenous peoples and nationalities, where solutions usually come from natural materials that, if used sustainably, offer viable alternatives. The recovery of these techniques is part of the UNESCO guidelines (2024) on safeguarding intangible heritage and the SDG11 Sustainable Development Goals, which promote sustainable and resilient cities.

The local *bahareque*, appreciated for its seismic resistance and thermal efficiency, is at risk of disappearing; this threatens ancestral knowledge and cultural identity (Lozano Guamán, 2021). Its rescue and adaptation are fundamental to preserving the heritage. Spreading good constructive practices with *bahareque* (wattle and daub) is essential to revitalize this technique and recognize its value (Corrales Blanco et al., 2021).

VERNACULAR ARCHITECTURE

Vernacular architecture is a cultural testimony that arises from the adaptation of communities to their natural environment, using local materials and techniques transmitted across generations (ICOMOS, 1999; Guerrero Baca, 2017). It represents an anonymous and collective way of being; it reflects the history and customs of the community (Calderón, 1985; UNESCO, 2003). Historically linked to the geographical, social, and economic context, it has been adapted to respond to housing needs with the available resources. It is functional, sustainable, and a means to preserve the cultural identity of the indigenous peoples over time.

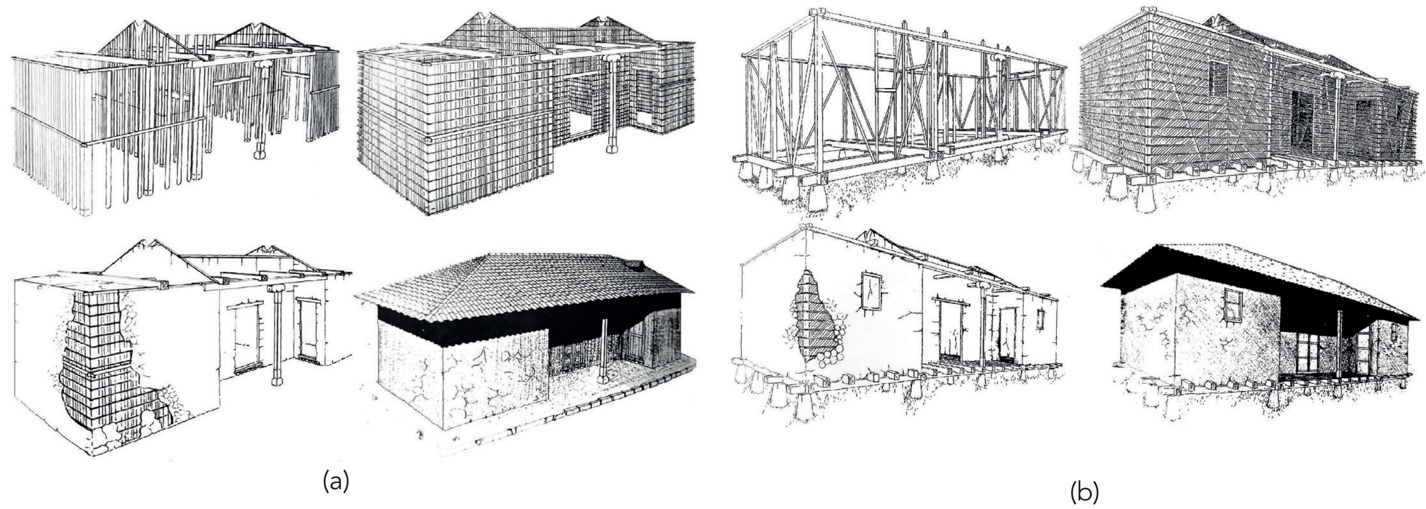

Figure 1. (a) Upright bahareque; (b) galluchaki bahareque. Source: Images taken from Calderón (1985).

BAHAREQUE IN THE KICHWA SARAGURO PEOPLE

The *bahareque*, in its local form, is used by the Kichwa people of Saraguro in the southern Ecuadorian highlands. It uses local materials such as wood, clay, and chincha (suro or *Chusquea scandens Kunth*). There are two variants in Saraguro: the upright *bahareque* and the *galluchaki bahareque* (or houndstooth) (Figure 1).

The upright *bahareque* has a vertical wooden framework anchored in the ground with stone bases to prevent moisture, which provides greater resistance (Calderón, 1985). It takes advantage of the orientation of the sun and the wind to improve indoor comfort (Pacheco, 2007). Deforestation and environmental regulations have led to the replacement of the "hill wood" (native term) with eucalyptus. The *galluchaki bahareque* is raised on stones to avoid moisture. The floors and beams are assembled between the carved wooden pillars, which improves structural stability (Calderón, 1985). The mud mixture, which covers the *chincha chagleado* (latticework), incorporates páramo straw (*Calamagrostis effusa*) and dry leaves, which gives a resistant and versatile finish.

In addition to their architectural value, these systems encourage community cooperation in building *mingas* and rituals, such as the *huarcuna*, which involves swinging from a structural part of the house after the *embarre* (rural community construction process) and weaving to validate its resistance. *Bahareque* is fundamental to the preservation of the cultural identity of Andean communities; its revitalization is essential to address the current housing and climate challenges (Lozano Guamán, 2016).

The purpose of this research is to revitalize the traditional *bahareque* construction system used by the Kichwa Saraguro people, through its characterization and updating from an integral approach that articulates both technical and cultural dimensions. It seeks to rescue this ancestral knowledge not only as a current constructive technique but also as a manifestation of both material and intangible heritage, which strengthens community identity and promotes sustainable practices in the region. To achieve this purpose, the following specific objectives are proposed: to characterize the traditional materials and techniques of *bahareque*; to experimentally evaluate the resistance and adhesion of the earth combined with local vegetable fibers; to design and structurally analyze a modular panel adaptable to contemporary porch systems; and to validate its technical and socio-cultural feasibility through a participatory practical workshop.

METHODOLOGY

This research employs a mixed-methods approach, combining qualitative and quantitative analysis with descriptive and experimental methods, as well as practical and community validation. It was organized in four main stages: selection and analysis of materials; design and structural analysis of the *bahareque* panel; application proposal and practical workshop; monitoring and evaluation.

SELECTION AND ANALYSIS OF MATERIALS

The selection of soils, materials for trusses, and fibers from the locality, along with the analysis of their physical characteristics, evaluation of compressive strength, and adhesion tests, was carried out.

Two soil samples were taken, sample 1 was taken near the Saludable Park of Saraguro, where the *bahareque* panels were later built, and sample 2 was from the community

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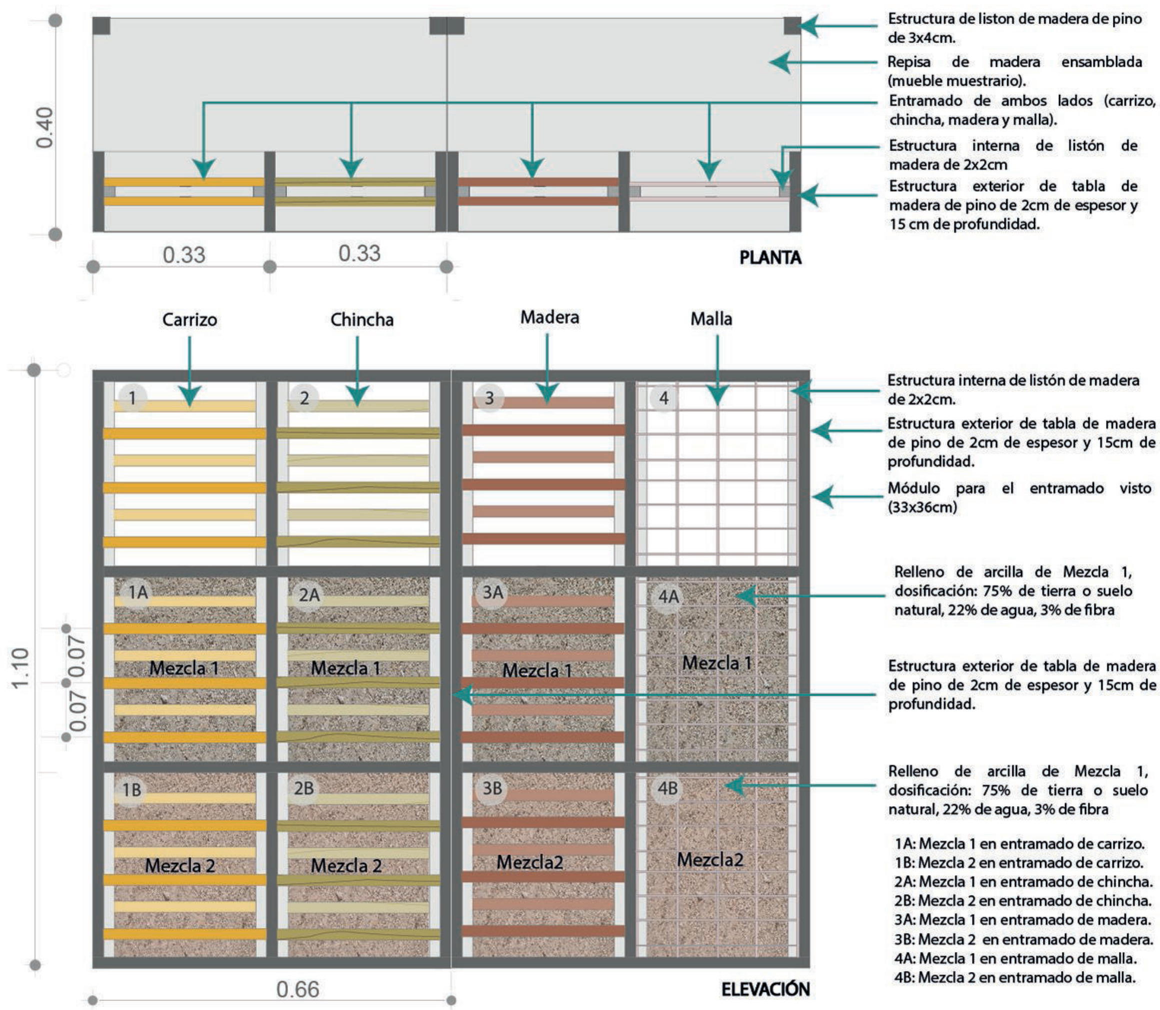

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Figure 2. (a) Floor plan and elevation of the truss sampler. (b) Preparation of the dosed mixture. (3) Application of the mixture in the reeds, chincha, wood, and mesh structures. Source: Preparation by the Authors.

of Las Lagunas, where the practical workshop was later held. The proximity to existing earthen constructions and the construction site, as well as the availability of suitable soils, were the key criteria for selecting these locations.

The field and laboratory tests on the samples included analysis of particle size, moisture content, liquid limits, and plasticity. At the same time, field sedimentation tests were conducted to analyze the soil's properties under humid conditions and classify it according to its texture. This procedure makes it possible to classify soils into strips of clay, silt, or sand, determining their applicability in various construction techniques (Pahaut et al., 2020).

The field test of the roll was carried out to identify simply the amount of clay in the soil samples and determine the appropriate dosages for use in the construction system: the soil sample is ground to a fine material; water is added to form a paste and a roll of 2 cm in diameter is formed. The breakage strength of the roll was evaluated according to the protocol of Pahaut et al. (2020): at 7 cm, the clay is insufficient; between 7 and 14 cm is ideal, and at more than 14 cm, it is excessive.

Earth test bodies were made with páramo straw fibers, pine leaves and puquín (dried leaves of the corn cob), the Spanish regulations UNE-EN 1015-11:2000/A1

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(2007) were used, which establishes the test methods to determine flexion and compression resistance in masonry mortars, with adaptations for materials such as earth, taken from the analysis methodology used by Gonzalo Sánchez (2012).

According to the standard, the dosage of 75% soil or natural soil, 22% water and 3% of a mixture of naturally dried fibers (8g of fiber per 200g of soil) was used to make five 10x5x5 cm specimens for each soil sample, they were dried for seven days and then subjected to compression tests in the laboratory.

Additionally, an adhesion analysis was conducted by constructing modular panels with various lattice types (Gonzalo Sánchez, 2012). In each module, a mixture of mud with páramo straw, pine, and puquín fibers was applied (1.5g of each fiber). For three weeks, the adherence of each mixture in the different lattices was monitored (Figure 2).

The adhesion of a mixture of earth and natural fibers on different lattices was evaluated, and the level of cracking was observed in a thickness of 12 cm. In the traditional method of the Kichwa Saraguro people, the use of the chincha (Andean bamboo or zuro) offers high adhesion due to its rough and irregular surface, which reduces the separation between materials. To compare their performance, similar tests were applied on rectangular wooden slats, chicken coop mesh, and peeled reed. These tests show the difference in the cohesion of the materials, highlighting the effectiveness of the traditional system (Gonzalo Sánchez, 2012).

DESIGN AND STRUCTURAL ANALYSIS OF BAHAREQUE PANEL

The formal design of the panel was based on the *bahareque* construction system technique, *galluchaki*, and aesthetically reflected in Andean iconography, as seen in the graphics comprising diagonal and successive elements, which are found in the textiles of the Kichwa

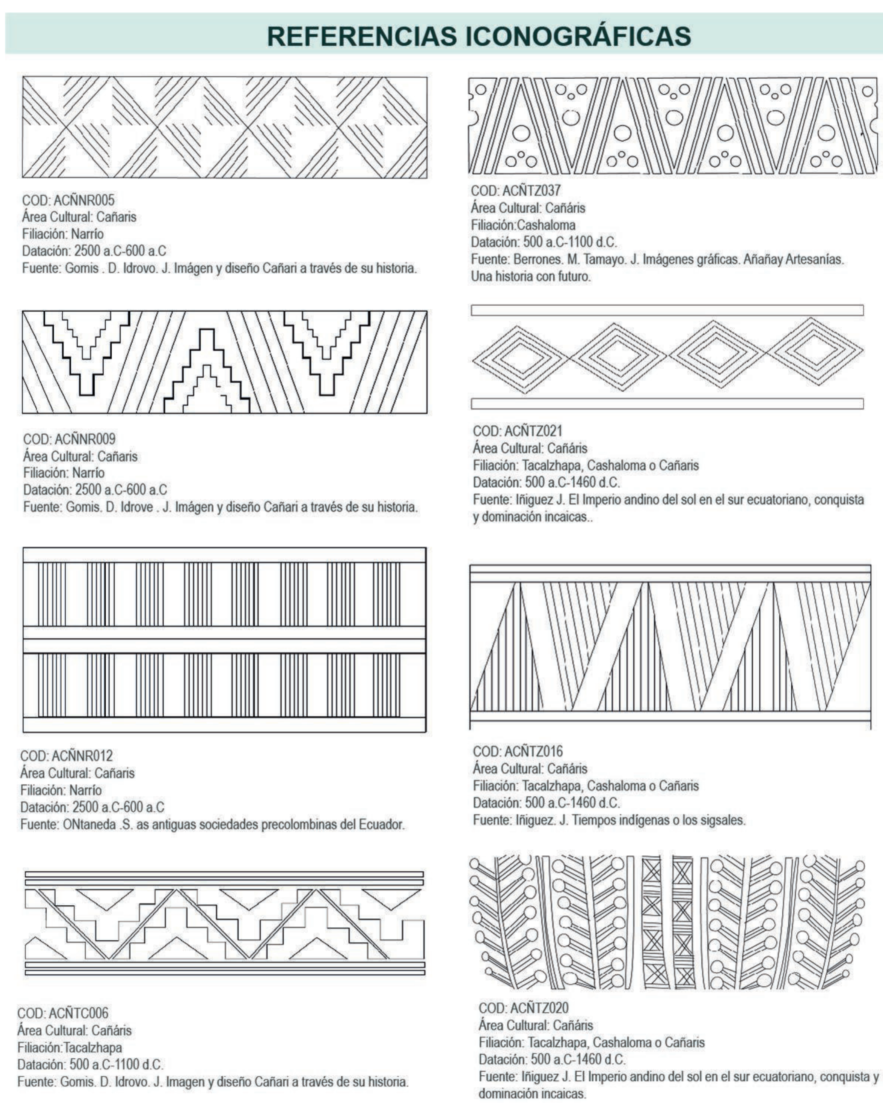

Figure 3. Iconographic references for the development of proposals for the structural geometry of bahareque panels. Source: Image taken from Martínez et al. (2015).

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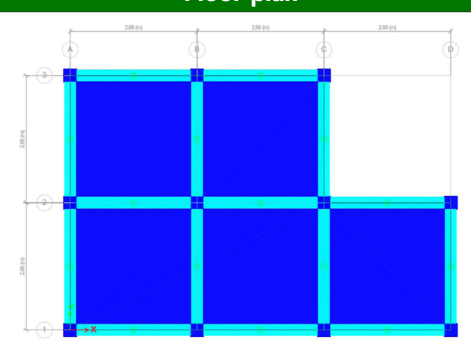
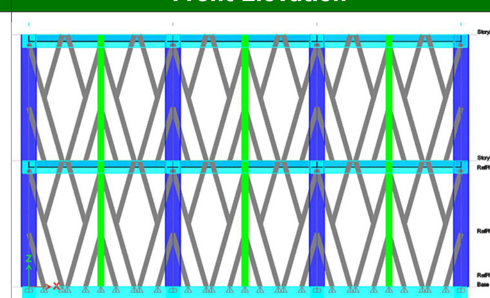
Table 1. Properties of eucalyptus for the panel structure. Source: Junta del Acuerdo de Cartagena (1984).

Type : B	Property	Value
EMIN	Modulus of elasticity.	75,000 kg/cm2
SW	Specific weight	1,000 kg/m3
EPROM	Modulus of elasticity	100,000 kg/cm2
FM	Resistance to momentum	150 kg/cm2
FC	Resistance to parallel compression	110 kg/cm2
FC P	Perpendicular compressive strength	28 kg/cm2
FV	Resistance to parallel cutting	12 kg/cm2
FT	Parallel tensile strength	105 kg/cm2

Table 2. Analysis model with reinforced concrete gantry system. Source: Preparation by the Authors.

Detail	Value	Floor plan	Front Elevation
Number of floors	2		
Mezzanine height	2.52 m		
Distance between the X-axis	2.88 m		
Distance between the Y-axis	2.88 m		
Irregularity in the floor plan	Yes		
Irregularity in elevation	No		

Saraguro people and their neighboring Kichwa Cañari counterparts (Figure 3).

The design of the panel considered the possibility of adapting it to wooden portico structures, reinforced concrete, metal, or even stone or adobe load-bearing walls. The proposal aimed to optimize the use of materials, reduce costs, and construction times, while using materials accessible in the local market.

The resistance of the panel was analyzed using the SAP2000 software, which considered the structural material to be eucalyptus wood, with the properties listed in Table 1.

The interaction between the wooden panels and a porticoed structure was analyzed structurally. The *bahareque*-type panels were incorporated into a reinforced concrete porticoed system to evaluate their impact on the transmission of loads and the rigidity of the structure (Table 2). Gravitational and seismic loads were included.

The standards NEC-SE-DS (Ministry of Urban Development and Housing [MIDUVI], 2014a) for seismic analysis, NEC-SE-GC (MIDUVI, 2014b) for non-seismic loads, and NEC-SE-HM (MIDUVI, 2014c) for reinforced concrete were applied.

The constructive details of the panel were developed using Archicad. An attempt was made to facilitate prefabrication and assembly and reduce the mud-caking time.

The prototype of the panel was built based on the results obtained; eucalyptus and chincha wood were used. For the first filling layer, soil from samples 1 and 2 was used in equal proportions, combined with fibers such as puquin and pine leaves. For the plastering, sample 1 was used, which included 15% finely chopped fibers and natural additives such as cane honey, aloe, and white glue.

The unit price analysis (UPA) of a panel was performed after its construction, when the performance was clear.

PROPOSAL FOR IMPLEMENTATION - PRACTICAL WORKSHOP

Three proposals for the application of the panel in different types of porticos were developed to demonstrate the

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possibilities of integration in wooden, concrete, or metal structures. For this, the distribution of porticos used in the structural analysis was used. Archicad was used as a visualization tool.

To disseminate the proposal and evaluate its feasibility for construction through *mingas*, a practical workshop was held, where students, parents who are community members, teachers, and professionals in architecture participated. The workshop was held over two days, beginning with an introduction to the importance of bioconstruction in today's world. Then, the procedures for identifying the types of soil were explained. The natural fibers were prepared, and the mud was mixed, which was applied as the first layer on the wall of the Community Educational Center *Inti Raymi* (CECIB *Inti Raymi*). Finally, the mortar for plastering, incorporating binders and natural fibers, was prepared and applied to a *bahareque* wall of the Andean House, a ceremonial space within the community school.

MONITORING/EVALUATION

To evaluate the technical, social, and cultural impact of the practical workshop, a longitudinal follow-up process was proposed from a participant observation perspective. Given her membership in the community technical team of Chukidel Ayllullacta, the principal researcher is in a strategic position to continuously document the appropriation and replication of the construction system at different scales of the region.

THE FOLLOW-UP INCLUDES:

- Registration of spontaneous adoption processes of the system, especially by families or groups that did not participate directly in the workshop.
- Evaluation of the level of understanding and autonomous reproduction of the techniques taught.
- Identification of improvements or adaptations made by users.
- Observation of the social and symbolic dynamics associated with the construction with bahareque.

This process enables the assessment not only of the system's technical effectiveness, but also its transformative potential as a tool for architectural, social, and cultural revitalization in the region. Special attention is paid to how traditional constructive knowledge is re-signified in contemporary contexts, and how collective practice (*minga*) favors its intergenerational transmission.

In summary, this methodology integrates technical design, constructive experimentation, and socio-cultural evaluation in a holistic process that articulates academic and community knowledge around the vernacular architecture of the Kichwa Saraguro people.

RESULTS AND DISCUSSION

ANALYSIS OF MATERIALS

The granulometric analysis of the soils in the laboratory indicated that the composition of sample 1, with a moisture content of 17.71%, was 67.3% sand and 32.7% fines. In contrast, sample 2, with a moisture content of 32.69%, consisted of 1% gravel, 19.4% sand, and 79.6% fines (silt and clay).

When comparing the results of the sedimentation test with those of the laboratory, similar data were obtained. In the soil classification pyramid (Pahaut et al., 2020), it is observed that sample 1 is a sandy loam soil, while sample 2 is on the boundary of a clay loam and a loam soil. This means that Sample 1 is more recommended for plasters, and Sample 2 for fillers (Figure 4).

At the roll test (Figure 5), in sample 1, with a single dosage, the average breakage occurred at 8 cm, ideal for *bahareque*; with 1 part sand and 1 part clay, it was at 6 cm, suitable for plasters. In sample 2, without rupture in three tests, it indicates a high amount of clay, ideal for craftsmanship, but for *bahareque* it needs more fiber to avoid cracks; with 1 part of clay and 2 parts of sand, it occurred at 11 cm, suitable for *bahareque*, and with 1 part of clay and 3 parts of sand, at 7 cm, suitable for plasters. This clay can also be used in paints and plaster, providing glossy finishes.

In the laboratory tests of the compressive strength of the bars (Table 3), the results show that the fibers significantly increase the resistance of the samples, with pine and puquín leaves being the most effective, which justifies their use in panel construction. The páramo straw was discarded due to its ecological role in the Andean páramos, where it is essential for water conservation. In its replacement, pine and puquín leaves were used, materials that offer a viable alternative to straw and a lower environmental impact.

In the adhesion tests, the materials proved to be suitable for the trusses, but they showed different adhesion behaviors with the first layer of clay and fiber:

- **Common reed grass (*Carrizo*):** High adhesion due to its smooth and round surface, but it is affected by the retraction of the mud; its lack of irregularities or porosity prevents a complete fixation, so a crack is generated between both materials. To improve its performance, it is recommended to divide the thick canes and place the more porous face towards the mud.
- **Chincha:** Favorable adhesion is achieved thanks to its wide canes and its semi-smooth, more porous outer surface, which allows for better interaction with mud and fiber, as the cracking between the materials

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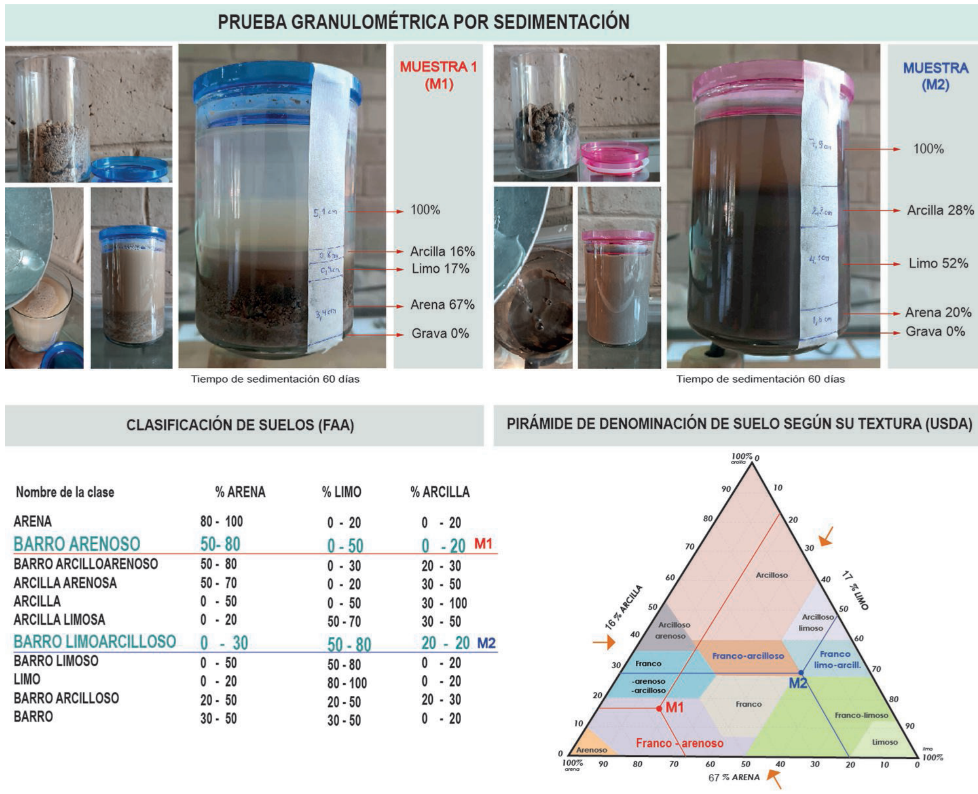

Figure 4. Granulometry results of samples 1 and 2 in the soil classification pyramid according to their texture. Source: Preparation by the Authors based on Pahaut et al. (2020).

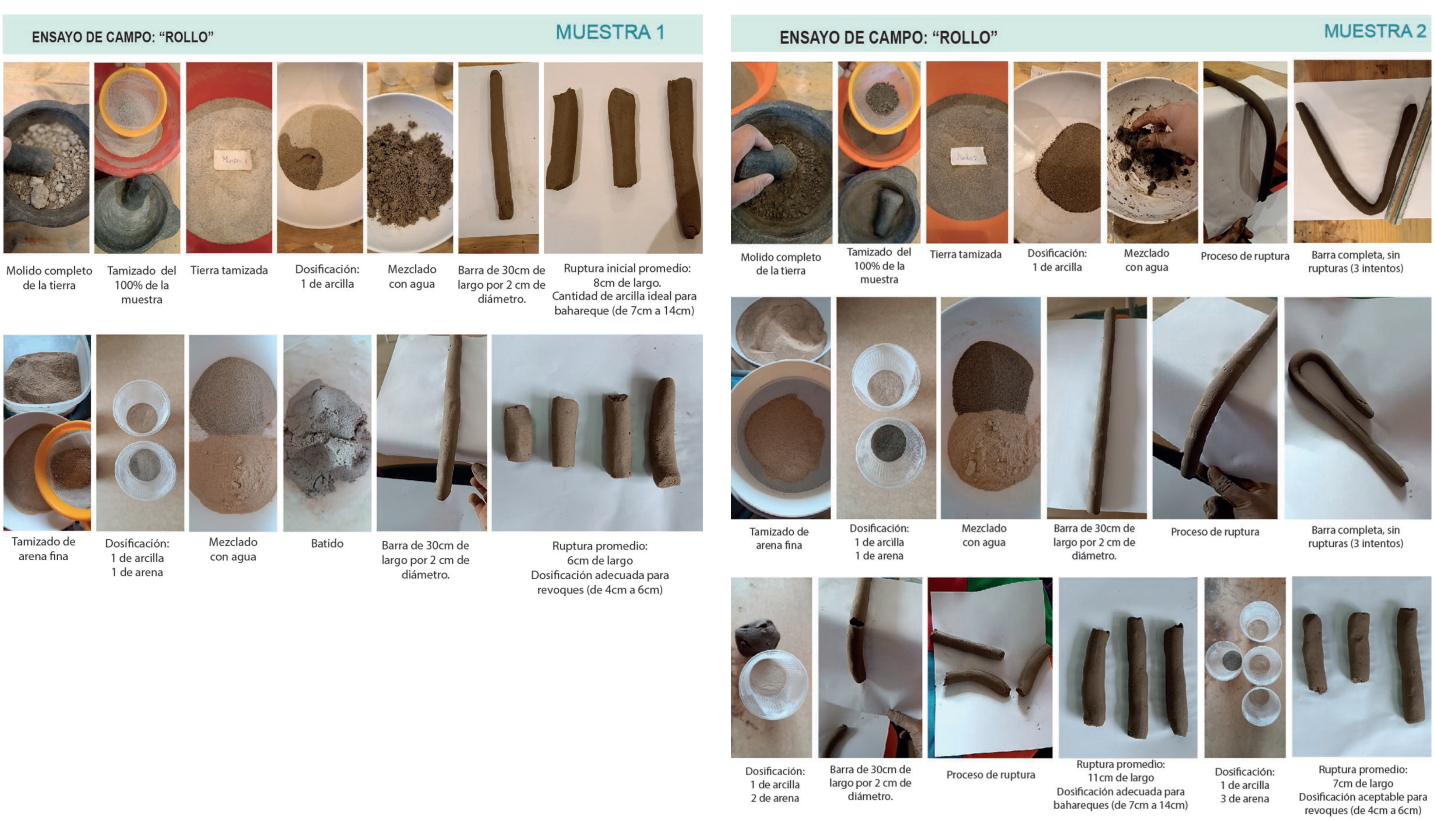

Figure 5. Roll-type field test (a) Sample 1; (b) Sample 2. Source: Preparation by the Authors based on Pahaut et al. (2020).

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Table 3. Results of the compressive strength in bars, samples 1 and 2. Source: Preparation by the Authors.

	Description	Área (cm²)	Load (Kg)	Resistance (Kg/cm²)
Sample 1	Empty	33.75	1455	43.11
	Straw	45	15460	343.56
	Pine	45	13876	308.36
	Puquín	45	27040	600.89
	3 fibers	45	10029	222.87
Sample2	Empty	33.75	2975	88.15
	Straw	45	13325	296.11
	Pine	45	14622	324.93
	Puquín	45	22205	493.44
	3 fibers	45	13405	297.89

is minimal. It is suggested to use the chincha in an inversely proportional way to ensure efficient drying with minimal shrinkage.

- **Wood:** The high porosity of its faces favors adhesion with the filling. The slats, placed between 5 and 7 cm apart, retain the fibers and prevent slipping and cracking during drying.
- **Mesh:** Excellent adhesion due to the metal structure and the small diameter of its rods, but it was seen that it is not an indigenous material and can overheat, which affects the internal humidity of the mud. It is recommended to use it in interior plasters where there is limited exposure to sunlight to avoid unfavorable cracking.

DESIGN AND STRUCTURAL ANALYSIS OF THE BAHAREQUE PANEL

The design of the *bahareque* panel incorporates geometric elements derived from Andean iconography such as triangles, rhombuses, and figures of axial symmetry. These patterns not only symbolically enrich the proposal but also serve a structural function, as the triangles and rhombuses are integrated as external diagonal braces and internal reinforcements of the lattice, providing rigidity and stability to the panel. In this way, the structural functionality of the system is merged with the Andean symbology and cosmovision.

An abstract symbol of the corn cob and geometric patterns present in the textiles and festivities of the Kichwa Saraguro culture were identified (Figure 6). These represent the duality of life, balance and cosmic order, which were adapted to build a contemporary structural system. In the Kichwa language, *Sara* (maize) and *Kuru* (worm) further enrich the cultural significance of the proposal.

Figure 6. Iconographic analysis and geometry design concept. Source: Preparation by the authors based on Martínez et al., 2015, and Inga, 2021.

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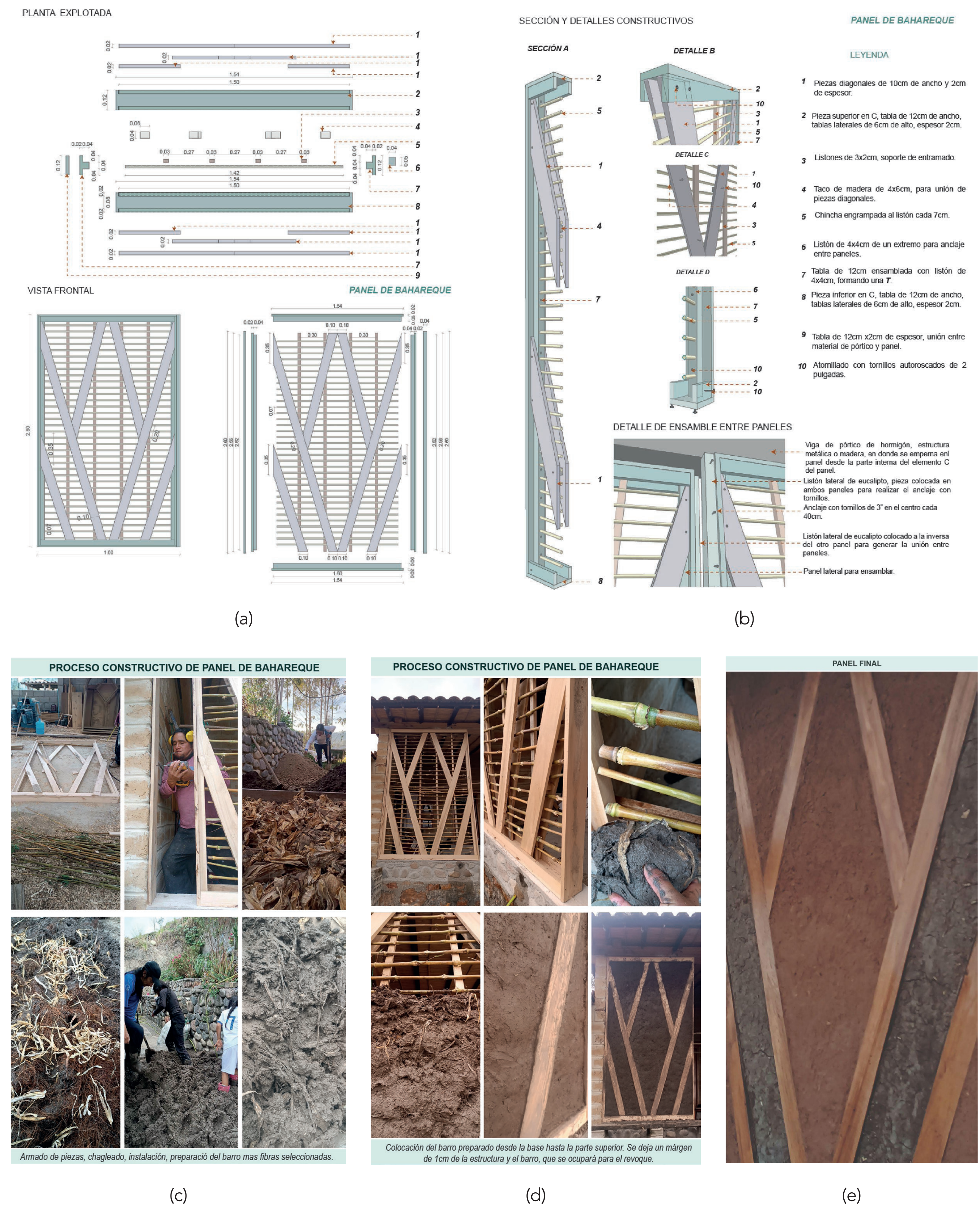

Figure 7. Proposed panel (a) disassembly; (b) details; (c) Photographs of the construction process, and (d) final result of the panel. Source: Preparation by the Authors.

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Table 4. Tests for resistance to elastic buckling and compressive strength. Source: Preparation by the Authors.

Element	Section diameter (m)	Effective length (m)	Critical buckling Pcr (kg)	Compressive strength (fc= 110 kg/cm2)	Maximum axial (Kg-m)	State
Vertical frame	0.12	1.6	39242	12441	1806	Complies with
Main diagonal brace	0.8	2.43	3356	5529	474	Complies with

Table 5. Flexion resistance check. Source: Preparation by the Authors.

	Section diameter (m)	Resistance to momentum (Kg-m)	Maximum momentum (Kg-m)	State
Vertical frame	0.12	509	22	Complies with
Upper horizontal frame	0.12	509	727	Complies with
Main diagonal brace	0.8	151	116	Complies with

The panels that make up the structure are made of 3x4 cm eucalyptus slats (the element that holds the chagliding), 4x4 cm (the element to join the panels), and 12x2 cm boards. Their construction and installation are simplified by using self-tapping screws, staples, and white glue putty. Figure 7 illustrates the proposed panel design.

Through the structural analysis of the panel, it was possible to verify that it meets the requirements for resistance to elastic buckling, compression, and flexion. The data obtained are presented in Tables 4 and 5.

STRUCTURAL ANALYSIS FOR THE APPLICATION OF THE PANELS IN PORTICOS

The inclusion of *bahareque* panels in structures with porticos reduces the vibration period from 0.31 seconds to 0.21 seconds, thereby improving the seismic response by decreasing flexibility and reducing the current seismic forces. Although this effect may be favorable, it requires a specific analysis in each case, as wooden panels and porticos (made of concrete, metal, or earth) absorb energy differently. When the panels have no structural function, the porticos must be designed in accordance with the corresponding regulations. Additionally, it is necessary to provide a technical joint between the panel and the portico to prevent unwanted rigidities or adverse effects.

The panel is fixed to the portico using an intermediate piece of wood (0.12m x 0.04m anchor plank) that is previously bolted to the existing portico, whether made of concrete, metal, or earth. This part serves as a flexible connector, protecting the integrity of the panel and facilitating its assembly. At the base of the system, there must be a stone stem wall or a wooden floor beam anchored to the floor or foundation, which levels and isolates the panel from direct contact with the ground, allowing the preservation of the natural moisture level of the panel materials. This modular joining system allows the adaptation of panels to various structural types without compromising their behavior or physical properties.

APPLICATION PROPOSAL

To visualize the application of the panels, housing proposals were made that used the same distribution of porticos used in the structural tests for one-, two-, and three-story houses (Figure 8).

- Wooden portico: A solution is proposed for one-story houses that integrates *bahareque* panels in conventional wooden structures. This allows reducing the amount of wood required, which maintains stability and functionality.
- Reinforced concrete portico: The application of *bahareque* panels is feasible in this system, with modifications to the height of the panels and the distribution of the porticoes to accommodate two-level buildings.
- Metal structure portico: In constructions of up to three floors, *bahareque* panels offer an efficient and sustainable solution that maximizes the use of local materials and integrates into the metal structure.

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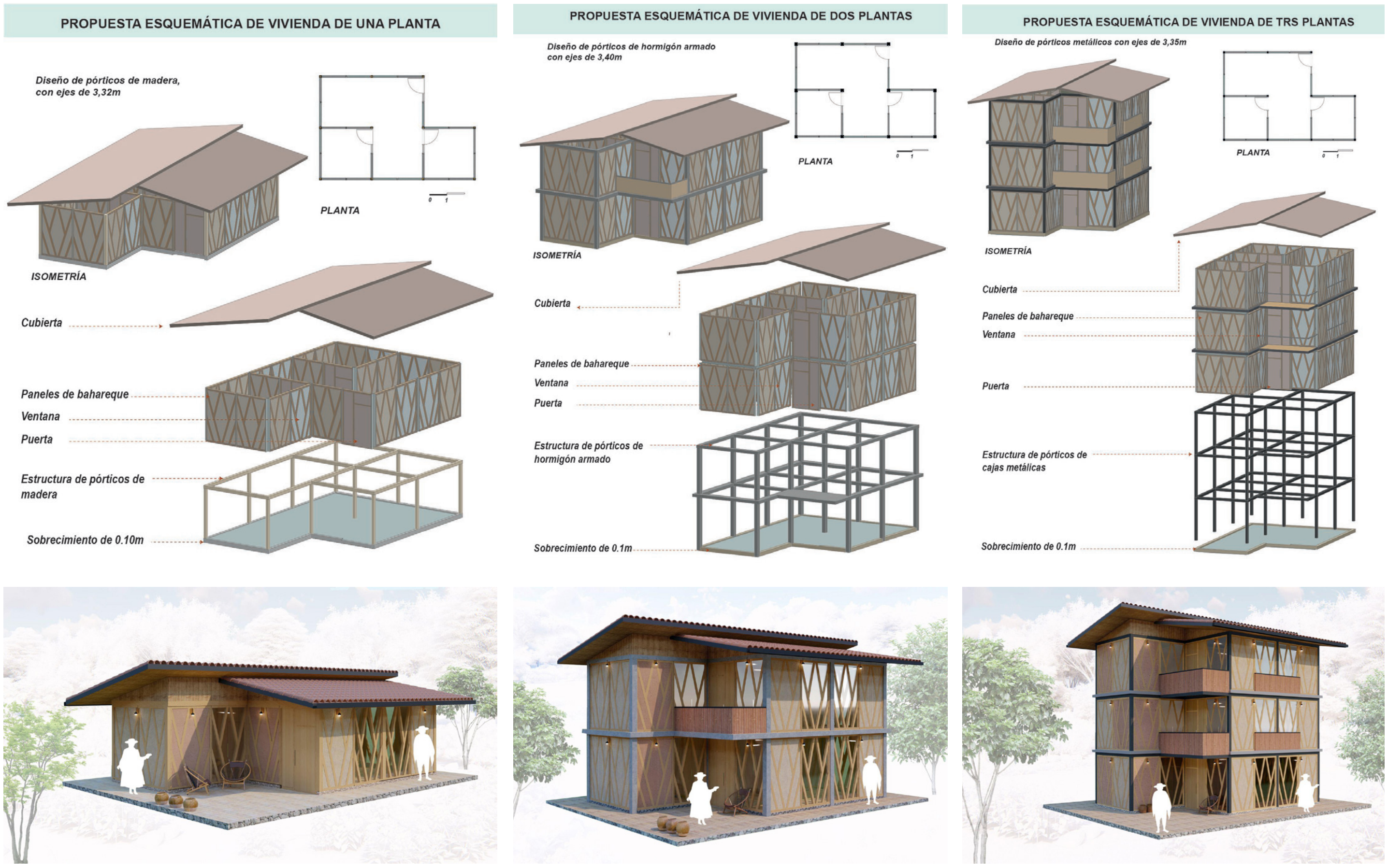

(a) (b) (c)

Figure 8. Schematic application of panels (a) Single floor house; (b) Two floor house; (c) Three floor house. Source: Preparation by the Authors.

BAHAREQUE PANEL UNIT PRICE ANALYSIS

The unit price analysis for a 1.60 m x 2.60 m bay panel considers four components: equipment, labor, materials, and transportation. A 5% charge is included for hand tools (USD 0.05) and the participation of a laborer and a mason, totaling USD 10.01. The materials (eucalyptus wood, screws, chinchas, mud with fibers, among others) total USD 132.00. Transportation is USD 3.00. The direct cost amounts to USD 145.06, to which 15% is added for indirect costs (USD 21.76) and 5% of profit (USD 7.25), totaling USD 174.07 as the offered value.

This amount is the cost per unit of the panel (4.16 m^2), equivalent to USD 41.84 per square meter. When compared to a block wall, which costs USD 64.39 per square meter (including cladding, plastering, and painting), the *bahareque* panel is 35% cheaper. Although wood finishes can increase the final value, the use of recycled and local materials helps keep costs down, positioning *bahareque* as a viable and accessible alternative within sustainable construction.

APPLICATION – SOCIALIZATION

Approximately 50 people participated in the bioconstruction workshop at CECIB *Inti Raymi*. The event took place over two days, with one hour dedicated to the theoretical workshop and 15 hours to the practical workshop. This activity facilitated the transmission of ancestral knowledge about construction, as it promoted interaction between generations and created a collective learning environment. Students from the last school grades, young local architects, and those from other cities worked together, overcoming the barriers of age, gender, and academic level.

Bioconstruction is not limited to fixed formulas, but should be an experimental and experiential process, as emphasized by Guerrero Baca (2017). The participants learned about the preparation of mud, the dosage of soils, and experimented with local fibers to improve the construction technique. This event allowed the youngest to reconnect with the *allpa mama* (Mother Earth) and strengthen their sense of belonging to the community and culture. In addition, it stressed the importance of sustainability and environmental care, raising awareness

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Figure 9. Images of the application workshop. Source: Preparation by the Authors.

about the need to preserve ancestral building practices and promote the responsible use of local resources. (Figure 9).

EVALUATION - IMPACT ON THE COMMUNITY

Following the workshop, coordination was conducted with community authorities to construct new spaces that promote collective participation and community gatherings, known as *mingas*. Additionally, in its professional practice, there was a growing interest in utilizing local materials for family projects. The dissemination of these collaborative processes has motivated councils of communities, such as Chukidel Ayllullacta, Gera, and Ilincho, of the Kichwa Saraguro people, in Saraguro Canton, Loja Province, south of Ecuador, among others, to undertake community *mingas* to build new spaces and revitalize existing ones.

Following the socialization of the construction process through the practical earth workshop and its dissemination on CECIB digital channels, Inti Raymi initiated a community process to build a collective kitchen using *galluchaki bahareque*. In addition, construction of a single-family house in the community began, in its traditional form, with a stone foundation, uprights on plinths, a diagonal brace, chincha and reed *chagleado*, and *embarre* (a rural local construction technique) using local natural fibers. An architectural object with metal porticos and *bahareque* panels was also proposed for commercial and tourist use within the community context.

The positive impact of promoting the preservation of constructive knowledge is observed, while also exploring new combinations of materials and strengthening confidence in the use of local resources, such as land, wood, and chincha, which adapt the system to the current needs of the population.

CONCLUSIONS AND RECOMMENDATIONS

The constructive system of *bahareque* of the Kichwa Saraguro people, particularly in its variant *galluchaki*, demonstrates a remarkable capacity for structural adaptation and material sustainability. Its implementation allows for a significant reduction in the use of industrialized materials by taking advantage of local natural fibers and ancestral methods with low environmental impact. The proper identification of the soil, the precise dosage of components, and the incorporation of plant structures have opened up possibilities for innovative applications in structural geometries, architectural finishes, and the active preservation of cultural identity.

This research contributes to the state of the art by systematizing constructive practices that integrate material and immaterial value, recognizing *bahareque* not only as a technique but also as a living cultural expression. Its contemporary application not only preserves what has been built but also reactivates community practices and rituals, which establish a bridge between ancestral knowledge and current habitat needs.

Although the structural calculations support the resistance of the constructions, the requirements for *bahareque* houses of one to three floors can be flexible, depending on the context and project conditions. An understanding of the basic principles of porticos and cross-beams is sufficient to ensure structural stability, as it allows a wide margin for experimentation and adaptation of this system to different architectural forms. The feasibility of these proposals will depend on economic factors and the level of detail in the construction, while also considering local traditions and their relevance in the current context.

The *bahareque* houses address housing needs and are a testament to the solidarity and collective work of the native peoples. Through this research, it has been demonstrated that the resistance and adaptability of the materials, as well as the acceptance they receive when participatory processes are promoted to disseminate the construction technique and its particularities properly, are key factors.

Finally, it is recommended that future research examine the quantitative aspects of the system more closely, such as the density and resistance of the mixtures, the final weight per module, thermal transmittance coefficients, and strategies to prevent thermal bridges between panels. Such data will allow refining the technical criteria for its normative validation, without compromising its cultural essence or its potential as a sustainable solution for rural and peri-urban habitats in the Andes.

CONTRIBUTION OF AUTHORS CRediT

Conceptualization, F.M.L.G., A.K.K.L.G.; Data curation, F.M.L.G.; Formal analysis, F.M.L.G.; Acquisition of financing, F.M.L.G.; Research, F.M.L.G., A.K.K.L.G.; Methodology, F.M.L.G., A.S.J.B.; Project management, F.M.L.G.; Resources, F.M.L. G.; Software, F.M.L.G.; Supervision, F.M.L.G.; Validation, F.M.L.G., A.K.K.L.G.; Visualization, F.M.L.G.; Writing – original draft, F.M.L.G., A.S.J.B.; Writing – revision and editing, F.M.L.G., A.S.J.B.

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