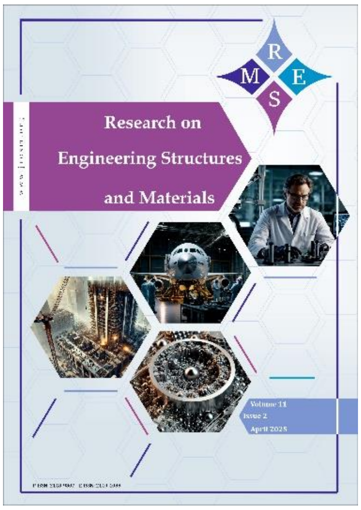
Research on Engineering Structures & Materials
www.jresm.org
Research Group



Evaluation of the physical and mechanical properties of pressed blocks and Caramelo blocks used in infill masonry for framed structures

Carlos Proaño, Michael Rodríguez, Alex Andrango, Juan Quilumba, Leslie Paspuel, Jason Guevara, Ana G. Haro-Baez

Online Publication Date: 10 December 2025

URL: http://www.jresm.org/archive/resm2025-1320me1106rs.html
DOI: http://dx.doi.org/10.17515/resm2025-1320me1106rs

Journal Abbreviation: *Res. Eng. Struct. Mater.*

To cite this article
Proaño C, Rodríguez M, Andrango A, Quilumba J Paspuel, L, Guevara J, Haro-Baez A G. Evaluation of the physical and mechanical properties of pressed blocks and Caramelo blocks used in infill masonry for framed structures. *Res. Eng. Struct. Mater*., 2025; 11(6): 3405-3425.

Research on Engineering Structures & Materials
www.jresm.org
Research Group

Research Article

Evaluation of the physical and mechanical properties of pressed blocks and Caramelo blocks used in infill masonry for framed structures

Carlos Proaño *[,a], Michael Rodríguez [b], Alex Andrango [c], Juan Quilumba [d], Leslie Paspuel [e], Jason Guevara [f], Ana G. Haro-Baez [g]

Department of Earth and Construction Sciences, Universidad de las Fuerzas Armadas-ESPE, 171-5-231B Sangolquí, Ecuador

Article Info

Article History:

Received 6 Nov 2025

Accepted 3 Dec 2025

Keywords:

Concrete blocks;
Compressive strength;
Water absorption;
Infill masonry;
Construction costs

Abstract

In framed buildings in Ecuador, concrete block masonry is an essential infill component. The coexistence of artisanal units ("caramelo block") and industrial units (pressed blocks) generates uncertainty about their technical performance and economic impact, as material selection is often based solely on unit price, disregarding construction efficiency. This study compared the physical–mechanical properties and cost–benefit of both block types manufactured in Latacunga, in Ecuador's central highlands. A total of 300 units were characterized through water absorption and compressive strength tests following NTE INEN 3066 and 3153. Masonry panels of 2 m^2 were built to quantify material consumption and labor productivity during masonry and plastering stages. Results showed that pressed blocks exhibited 109 % higher compressive strength (2.39 MPa versus 1.14 MPa) and 22 % lower water absorption. Neither block type met the standard's minimum compressive strength of 3.5 MPa. Despite their higher unit cost, pressed blocks proved 9.7 % more economical in masonry and 21.3 % in plastering per square meter. It is concluded that pressed blocks provide superior cost–benefit performance, challenging the perceived savings of artisanal blocks. These findings offer a quantitative basis for decision-making and emphasize the need for stricter quality control to ensure safer, more efficient construction.

1. Introduction

Concrete block masonry is one of the most widely used enclosure systems worldwide due to its low cost, ease of construction, and durability. In modern buildings with frame structures, these elements often serve a non-structural function, acting as infill masonry that delimits spaces, contributes to the building's lateral rigidity, and improves its thermal and acoustic performance [1,2]. However, despite not being part of the primary lateral load–resisting system, the physical and mechanical quality of the blocks directly influences deformation compatibility, cracking risk, the consumption of finishing materials, and the overall safety of the building, especially in seismic zones such as the Andean region of Ecuador. This is consistent with numerical studies showing that variations in concrete strength and seismic detailing significantly modify seismic damage probabilities in RC buildings [3].

In Latin American countries, concrete block production presents a marked duality between industrialized processes called pressed blocks (Fig. 1) and artisanal processes called "caramelo" blocks (Fig. 2). The former are manufactured through controlled mechanical compaction, which

*Corresponding author: ciproano@espe.edu.ec
[a]orcid.org/0000-0001-7329-1273; [b]orcid.org/0009-0003-5932-0252; [c]orcid.org/0009-0000-8476-0450; [d]orcid.org/0009-0005-6051-071X; [e]orcid.org/0009-0008-7559-6132; [f]orcid.org/0009-0003-0496-1896; [g]orcid.org/0000-0002-6415-4653
DOI: http://dx.doi.org/10.17515/resm2025-1320me1106rs

guarantees dimensional uniformity, lower porosity, and greater compressive strength; while the latter, made manually with metal or plastic molds, present geometric irregularities, greater absorption, and strengths below regulatory values [4]. This productive heterogeneity has a direct impact on the quality of the infill masonry, which must maintain sufficient stability against service loads and deformations imposed by the structural framework [5].

Fig 1. Pressed Block

Fig 2. Caramelo Block

At the international level, numerous studies have focused on developing more efficient and sustainable concrete blocks, aiming both to improve mechanical performance and to reduce environmental impact. In this context, [6] emphasizes that, although concrete underpins modern infrastructure and generates substantial economic value, its massive global production is responsible for a significant share of CO_2 emissions and intensive consumption of raw materials and water. Within this framework, [7] demonstrated that incorporating oyster shell, biochar, and bottom ash into permeable blocks improves strength and reduces wicking.[8] verified that partial replacement of the binder with steel slag allows maintaining strength and reducing volumetric expansion. [9] proposed the use of microalgal biomass to optimize the internal microstructure, while [10] and [11] explored the use of phase-change materials and recycled aggregates to improve thermal performance and reduce density. These advances reflect the trend toward more controlled, sustainable, and energy-efficient concrete block production.

At the same time, there has been increasing interest in understanding the mechanical behavior of non-structural infill masonry, especially under seismic or differential load conditions. Recent research [1,12,13] have shown that the interaction between the block, mortar and structural frame significantly affects the lateral stiffness of the system and can induce stress concentrations that result in diagonal cracks or premature detachments. Likewise, [5] demonstrated that the method of mortar application (full-shell or face-shell bedding) influences the deformability and stress distribution in the prisms, which is relevant even in non-load-bearing masonry, where block uniformity determines mortar consumption and construction efficiency. In this sense, the quality of the blocks not only determines local resistance, but also mechanical compatibility with the frame, a critical aspect to avoid non-structural damage during seismic events [14].

In Ecuador, non-structural concrete blocks are the most used material for the construction of partition and enclosure walls in framed buildings. The Building Statistics Bulletin [15]indicates that more than 54% of registered homes use this type of masonry. The standard [16]establishes the minimum requirements for concrete blocks, including dimensions, density, absorption, and compressive strength. Those used in non-structural masonry with an individual strength of 3.5 MPa are classified as Class B blocks. Additionally, the standard [17] regulates the procedure for the preparation and laboratory testing of low walls, allowing the masonry's compressive strength and structural efficiency to be determined. However, recent studies and field observations show that a large part of the blocks produced by hand in the country do not meet the established minimum values, which compromises the quality of the enclosures and increases the costs of finishes due to the greater consumption of mortar and plaster [18].

In this context, the city of Latacunga, located in the central highlands of Ecuador, constitutes a strategic point for analyzing the quality of masonry materials. Its geographic location, in an intermediate seismic zone, and the availability of volcanic aggregates from the Andes Mountains influence the composition and behavior of locally manufactured blocks. Small artisanal factories and semi-industrial plants coexist in the city and its surroundings, supplying both the local market and that of the central region of the country, with wide variability in quality control, curing, and compaction. However, to date, there has been no research experimentally comparing the physical and mechanical properties and construction efficiency of pressed and industrial blocks versus artisanal caramelo-type blocks produced in Latacunga.

In addition to mechanical performance, economic and construction aspects are decisive in the selection of block type. Previous research [4, 19, 20] agrees that the initial cost of a handmade block is usually lower, but the total construction cost increases due to dimensional irregularity and greater absorption, which require more mortar and greater plaster thickness to achieve flat surfaces. This phenomenon is accentuated in infill masonry, where geometric regularity is essential to ensure proper anchorage to the frame and the continuity of the finishes. Therefore, evaluating block performance not only in terms of strength, but also in relation to its impact on construction performance and the overall cost per square meter, is essential to optimize the productivity and sustainability of local construction.

This research aims to comparatively evaluate the physical and mechanical characteristics and associated costs of pressed and industrial concrete blocks versus artisanal caramelo-type blocks used in nonstructural infill masonry in framed buildings. The study integrates standardized laboratory tests according to [16] and [17], with construction performance measurements and unit price analysis, allowing for a correlation between mechanical performance and economic and construction impact.

This work provides unprecedented experimental evidence for the central Sierra region of Ecuador and constitutes a technical reference for improving manufacturing processes, quality control, and material selection for nonstructural masonry. Furthermore, the results reinforce the importance of complying with national standards as a condition for ensuring the efficiency, durability, and structural compatibility of infill masonry in framed buildings, while promoting the sustainability and competitiveness of the local construction materials industry.

2. Materials and Methods

The study was structured in three phases (Fig 3): Phase 1 consists of the analysis and characterization of the sand and cement materials; Phase 2 focuses on testing of composite elements such as mortars, blocks, and walls to evaluate them against the requirements of Ecuadorian technical standards and establish their physical and mechanical properties; and finally, Phase 3 quantifies the materials and performs unit price analysis for block masonry and vertical plastering.

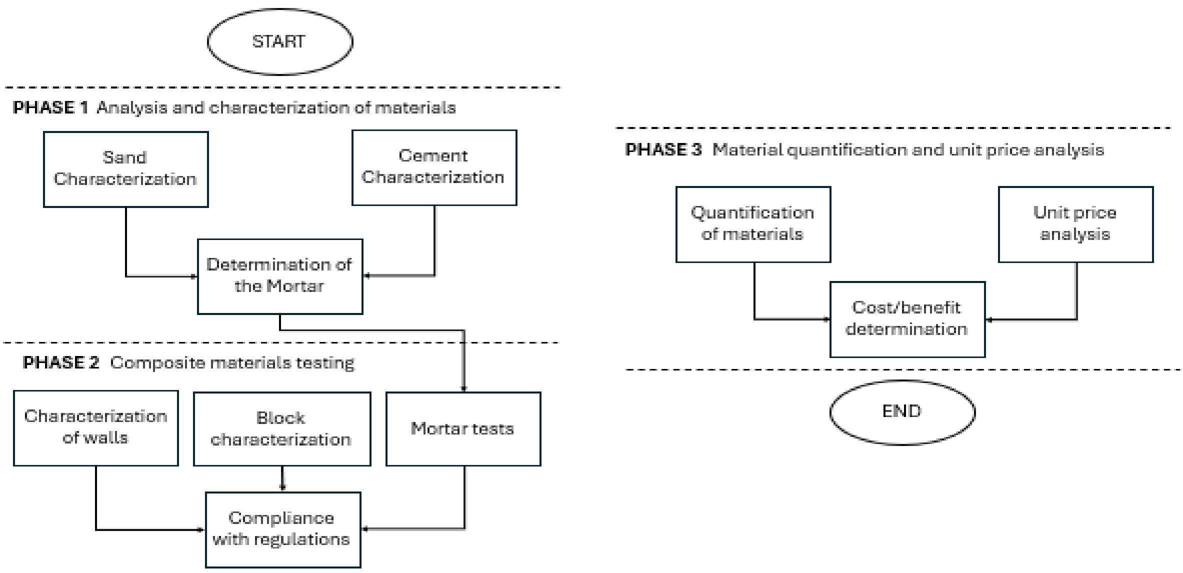


Fig. 3. Research outline

2.1. Phase 1. Material Analysis and Characterization

The materials used in the construction of the masonry were characterized:

2.1.1 Sand Characterization

The specific gravity and water absorption of the sand were determined on a 500g oven-dried sample in accordance with [21]. Both tests were performed following the procedures specified in this standard (Table 1).

Table 1. Specific gravity and water absorption of sand

Description	Value
Specific gravity of soil at more than 20 °C	2.54
Water Absorption	2.04%

2.1.2 Cement Characterization

A general-use hydraulic cement (type GU) was used as the binder. According to the manufacturer's specifications, this cement complies with the performance requirements of [22] standard for general-use hydraulic cements.

2.1.2.1 Cement Density

Three samples of 64g of mass were taken using the Le Chartelier volumetric flask method (Fig 4) in accordance with [23] as shown in Table 2, although the standard does not establish a minimum or maximum number of tests to be performed.

(a) (b) (c)

Fig. 4. Cement density test (a)Cement mass, (b) Bottle of Le Chatelier with gasoline and (c) Le Chatelier's bottle with gasoline and cement

Table 2. Cement density

Sample	Mass (g)	Density (g/cm^3)
1	64.00	3.18
2	64.00	3.15
3	64.00	3.20
Average		3.18

2.1.2.2 Cement Consistency

Three 650g samples of cement were prepared using the Vicat method (Fig 5) in accordance with [24], presenting an average consistency of 28.45% as shown in Table 3.

(a) (b) (c)

Fig. 5. Cement consistency test (a) Mechanical mixer, (b) Mixed mortar and (c)Vicat's needle

Table 3. Cement consistency

Sample	Normal Consistency (%)
1	27.70
2	28.45
3	29.20
Average	28.45

2.1.2.3 Cement Setting Time

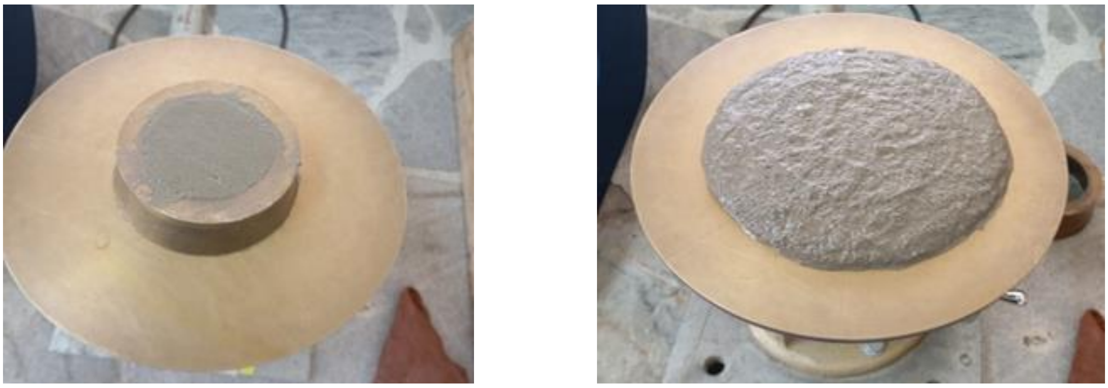
Fig. 6 shows the cement consistency test using the Vicat method, resulting in a setting time of 318 minutes according to *[25]*

Fig. 6. Setting test using the Vicat method

2.2 Phase 2. Composite Material Tests (Mortars, Blocks, And Low Walls)

2.2.1 Mortar Characterization

A mortar flow test was performed [26] , yielding a flow of 108 %, establishing the dosage: 1:2.75 (cement:sand) by mass with a water/cement ratio of 0.485 (Fig 7). Based on these results, 12 mortar cubes (Fig 8) with dimensions of 50mm x 50mm x 50mm were prepared and tested to determine their compressive strength in accordance with [27]. The cubes were divided into four groups of three specimens and tested in compression at ages of 1, 3, 7, and 28 days, following the requirements of [22]. For each age, the mean compressive strength of the three cubes was reported.



(a) (b)

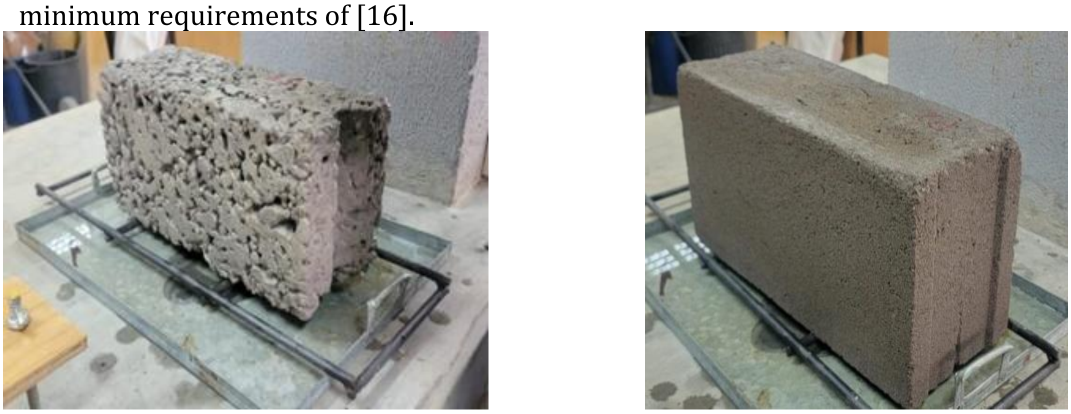
Fig. 7. Mortar flow test (a), Mortar in mold (b) Mortar on fluidity table

Fig. 8. Mortar cubes in mold

2.2.2 Block Characterization

A total of 150 caramelo blocks (handcrafted) and 150 pressed blocks (industrially manufactured) were purchased as standard commercial products from two local producers in Latacunga, located in the central Sierra region of Ecuador. These manufacturers routinely supply concrete masonry units for nonstructural masonry in residential and small building projects in Latacunga and surrounding areas. The blocks were taken directly from their current production batches, without any special pre-selection other than the visual inspection prescribed by [16], so that the tested units can be considered representative of the blocks commonly used in local practice. For each block type, the following tests were performed:

- Visual Appearance: Three blocks of each type were analyzed (Figure 9), according to the minimum requirements of [16].



(a) (b)

Fig. 9. Specimens selected for visual inspection, dimension measurement, and absorption testing (a) Caramelo block and (b) Pressed block

- Dimension Measurement: Three blocks of each type were used, according to [16].
- Water Absorption Tests: The three blocks of each type (Fig 10) were tested, according to [16].

(a) (b)

Fig. 10. Water Absorption Test on Blocks (a) Caramelo block and (b) Pressed block

- Dry Unit Density: Block density was determined in accordance with [16] using the oven-dry mass, saturated mass, and submerged mass of the same three units used in the water absorption test for each block type.
- Compressive Strength of Blocks: The standard [16] recommends testing at least 3 block specimens; however, 10 blocks of each type were tested (Fig 11) to obtain a broader range of results.

(a) (b)

Fig. 11. Compressive strength test of blocks (a) Caramelo block and (b) Pressed block

2.2.3 Characterization of Low Walls

According to [17], low walls of perforated units were constructed to evaluate the compressive strength of concrete blocks. Six specimens were made for each block type, using two blocks per wall. Each wall consisted of two courses (rows) of blocks, joined only by a horizontal mortar joint (1:2.75 cement:sand mix), without vertical mortar joints between the units.

The walls constructed with pressed blocks had a width of 24.8 cm and a total height of 41.5 cm, corresponding to a height-to-width ratio (h/b) of 1.67. Low walls made of caramelo blocks had a width of 24.6 cm and a height of 39.0 cm, with an h/b ratio of 1.59. These dimensions and proportions are consistent with the model of perforated unit walls specified in [17]. Due to the limitations of the testing machine, the blocks were cut following the geometric requirements of the standard, to preserve the configuration of the wall before carrying out the compression tests (Fig. 13).

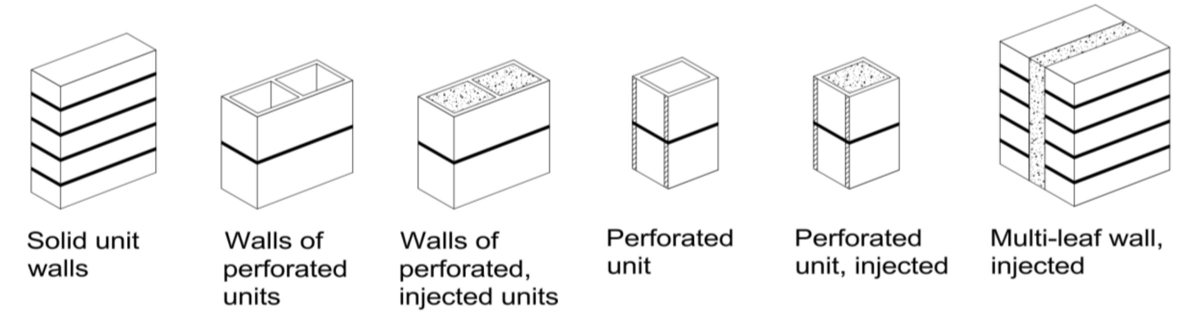


Fig. 12. Types of Low Walls

(a)

(b)

Fig. 13. Compressive Strength Test of Low Walls (a) Low walls and (b) Compression test of low walls

2.3 Phase 3. Material Quantification and Unit Price Analysis

To evaluate the construction and economic performance of the masonry units, three panels of approximately 2 m^2 were built for each block type (caramelo and pressed), with 25 blocks per panel, as shown in Fig. 14. The area of approximately 2 m^2 was selected because it provides a sufficiently representative surface area for the behavior of a masonry wall in construction and, at the same time, allows for more reliable quantification of material consumption and construction time per unit area. Constructing three panels per block type is aimed to introduce variability in the construction process and obtain more robust average consumption and yield values. Subsequently, both sides of the panels were plastered (Fig. 15). The plastering mortar was applied with a 1:4 dosage (cement:sand, by mass) and an average thickness of 1.5 cm, a value that is within the range usually used in construction practice in Ecuador (0.5–2.0 cm), and which corresponds to the most commonly used thickness to achieve a uniform surface in enclosure walls.

Fig. 14. Pressed block masonry

Fig. 15. Plastered Pressed Block Masonry

During construction, the following were recorded:

- Mortar consumption: In the masonry joints, with a ratio of 1:2.75 (cement:sand) to their mass, quantifying the volume used and the quantities of cement, sand, and water.
- Plastering mortar consumption: Applied to both sides of the masonry, with a ratio of 1:4 (cement:sand) to their mass and an average thickness of 1.5 cm, the quantities of cement, sand, and water were quantified.
- Effective areas of the masonry and plaster: To determine the ratio between materials used and the surface area covered.
- Activity execution times.: The start and end times of the work were recorded for both the wall construction and the plastering.
- Work crew composition.: The unit price analysis was prepared for the second quarter of 2025. The work team consisted of a mason and a construction assistant, under the supervision of a foreman. The hourly costs for each category were calculated based on the minimum wages in effect in 2025 for the construction industry, as established by the Comptroller General of the State of Ecuador.
- Cost of materials.: Caramel-type concrete blocks had a unit cost of USD 0.28, while pressed blocks had a unit cost of USD 0.45. The prices of cement, sand, and water were USD 0.15 per kilogram, USD 0.034 per kilogram, and USD 0.72 per m^3, respectively. These prices correspond to quotes obtained from local hardware stores and block manufacturers in the city of Latacunga, collected in May 2025, while the cost of water was taken from the basic services bills for the same month. Therefore, the cost analysis results reflect the market conditions prevailing in the second quarter of 2025.

Based on the collected information, unit price analyses (UPAs) were prepared for masonry and plastering activities, comparing the technical and economic performance of both types of blocks.

3. Results of Analysis

3.1 Phase 2. Composite Material Testing

3.1.1 Mortar Characterization

The compressive strength of mortar cubes (Fig 16) was tested in three samples at different ages (1, 3, 7, and 28 days). The results for 3, 7, and 28 days of age exceeded the minimum requirements established by the standard [22], as shown in Figure 17. There is no minimum age requirement for 1 day; however, the standard requires the test to be performed.

Fig 16. Compressive strength test of mortar cubes

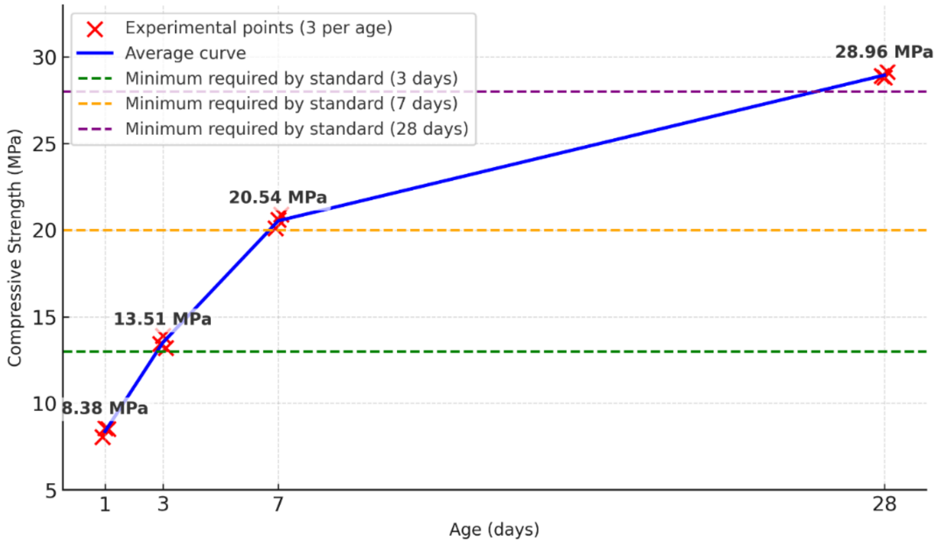


Fig. 17. Evolution of the Compressive Strength of Mortar compared to the Minimum Required by (NTE INEN 2380)

3.1.2 Block Characterization

3.1.2.1 Visual Appearance

The pressed blocks (Fig 1) have much better visual appearance than the caramelo block (Fig 2), especially in the dimensions, regular surface, and chipping established in the standard [16]. The caramelo blocks have surface voids and irregular edges; the comparison between the two is shown in Table 4.

Table 4. Analysis of visual aspects of the blocks

Block Appearance	Pressed Block	Caramelo Block
Actual dimensions outside tolerances ± 3 mm	Yes	Yes
Chips with a diameter greater than 25 mm on the block faces	No	Yes
Cracks with a width greater than 0.5 mm and lengths greater than 25% of the height on the block faces	No	No
Broken units	No	No

3.1.2.2-Dimensional Analysis

Notable differences were evident between the two types of blocks evaluated, considering that the nominal dimensions of the blocks to be tested are 390 mm long x 190 mm high x 140 mm wide.

Figure 18 presents the faces and dimensions taken from the blocks. Both the pressed blocks (Table 5) and caramelo blocks (Table 6) presented dimensions that exceeded the tolerance established in [16]. Figure 19 shows the difference in block dimensions and the accepted tolerance.

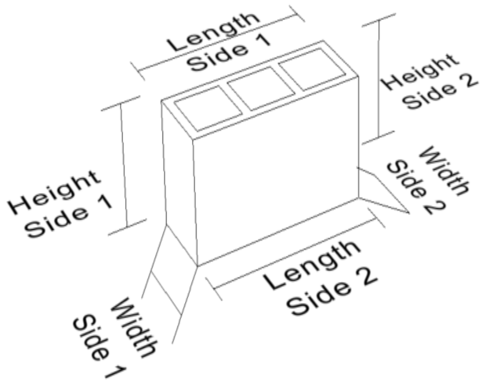


Fig. 18. Block Dimensional diagram

Table 5. Dimensions of the pressed block

Sample	Width			Height			Length		
	Side 1 (mm)	Side 2 (mm)	Maximum variation (mm)	Side 1 (mm)	Side 2 (mm)	Maximum variation (mm)	Side 1 (mm)	Side 2 (mm)	Maximum variation (mm)
P1	148	147	8	200	200	10	398	398	8
P2	147	148	8	200	200	10	398	398	8
P3	148	147	8	200	200	10	397	398	8

Table 6. Dimensions of the caramelo block

Sample	Width			Height			Length		
	Side 1 (mm)	Side 2 (mm)	Maximum variation (mm)	Side 1 (mm)	Side 2 (mm)	Maximum variation (mm)	Side 1 (mm)	Side 2 (mm)	Maximum variation (mm)
C1	135	136	-5	185	186	-5	376	375	-15
C2	135	136	-5	185	184	-6	377	376	-14
C3	135	134	-6	185	186	-5	374	375	-16

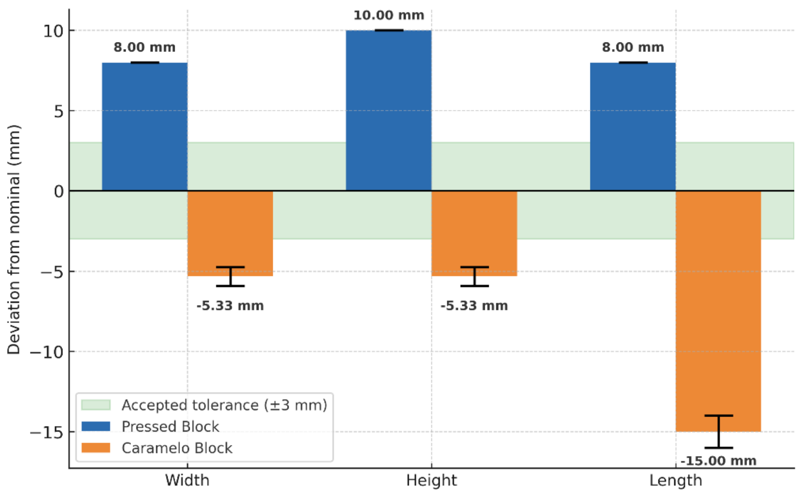


Fig. 19 Comparison of maximum dimensional variations vs tolerance [16]

3.1.2.3 Density and Water Absorption of Blocks

Table 7 shows the acceptable values for each block type according to [16]. Both types of blocks are classified as LIGHTWEIGHT, presenting densities below 1680 kg/m³. Furthermore, because they are non-structural, they are classified as Class B. Based on this classification, the standard establishes a maximum average water absorption of 288 kg/m³ for lightweight blocks. The standard does not establish maximum absorption values for Class B blocks, so Table 7 defined for Class A blocks was used. The pressed blocks met this requirement, registering an average of 267.82 kg/m³, while the caramelo blocks exceeded it with 343.38 kg/m³. Figures 20 and 21 show the comparison of the blocks' density and maximum water absorption values. The results show that the pressed blocks have a 22% lower water absorption than the caramelo ones.

Table 7. Maximum water absorption in Class A blocks

Type	Density (kg/m³)	Maximum average water absorption (kg/m³)	Maximum water absorption per Unit (kg/m³)
Light	< 1680	288	320
Medium	1680 a 2000	240	272
Normal	> 2000	208	240

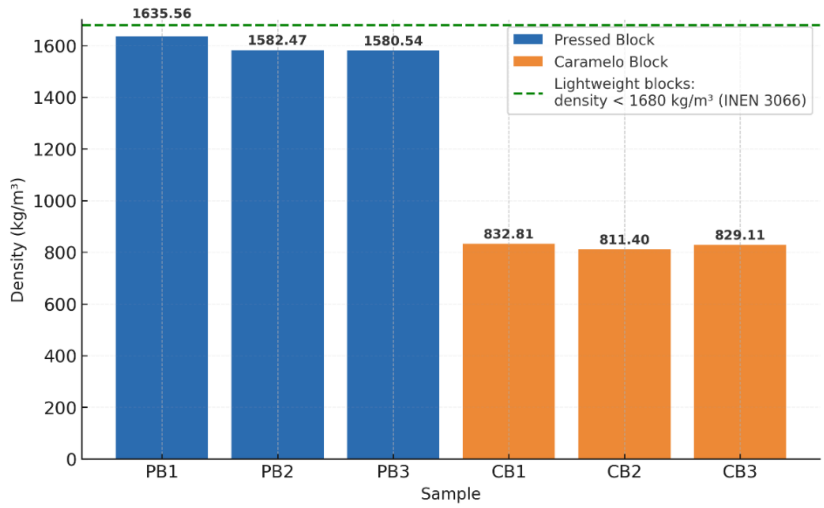


Fig. 20. Block classification according to [16]

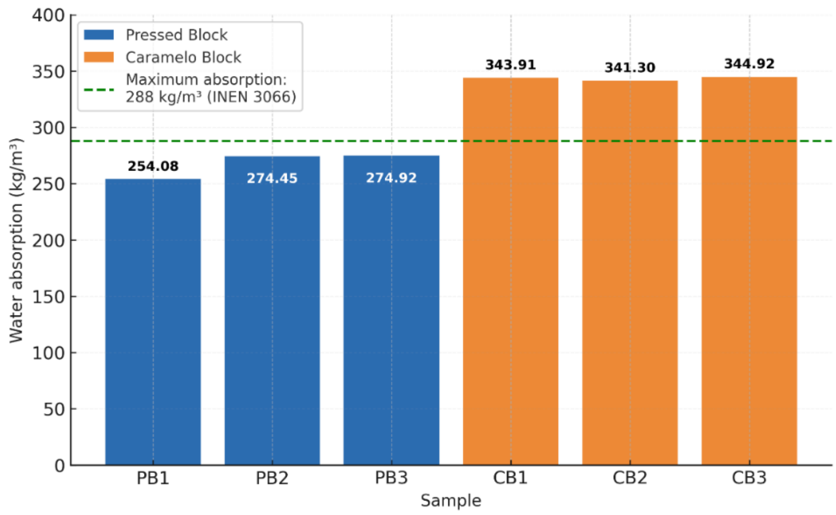


Fig. 21. Block Absorption vs. Standard [16]

3.1.2.4 Compressive Strength

The standard requires a minimum strength of 3.5 MPa per unit and an average of 4.0 MPa for Class B nonstructural blocks [16]. The pressed blocks reached an average of 2.39 MPa, and the caramelo blocks an average of just 1.14 MPa, with the pressed blocks being 109.58% higher. In both cases, the values are below the required values; however, the pressed block showed better relative performance, as shown in Figure 22.

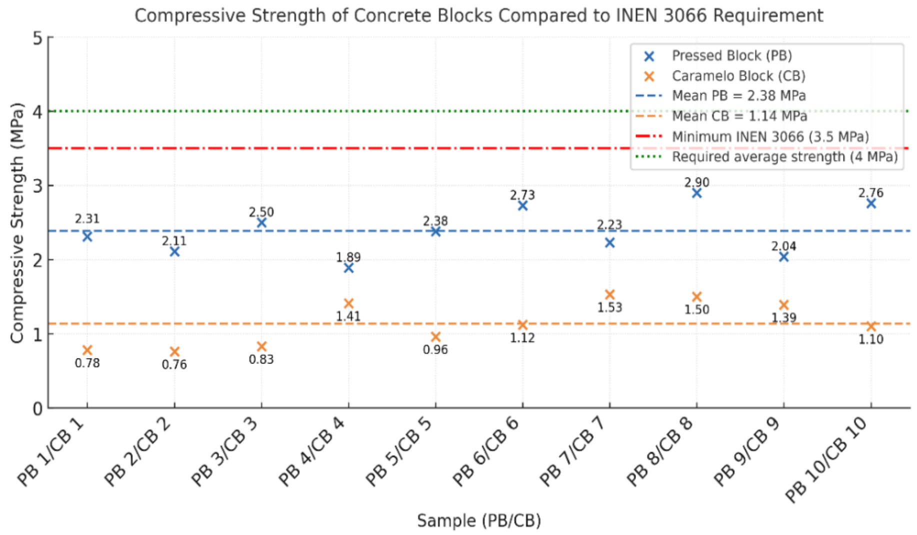


Fig. 22. Comparison of compressive strength of pressed blocks and caramelo

3.1.2.5 Compressive Strength of The Low Walls

The same trend was reflected; walls were built with dimensions of width, height, and thickness of 24.6 × 41.5 × 15 cm for the PB and 24.6 × 39.0 × 13.8 cm for the CB. Due to the height/width ratio of the low walls, the correction factor established in [17] was applied by interpolating the values in Table 8. The correlation factors are 0.91 for the pressed blocks and 0.89 for the caramelo blocks. The average strength achieved was 3.17 MPa for the walls built with pressed blocks and 1.05 MPa for the caramelo blocks, demonstrating a significant difference between the two systems, presented in Figure 23.

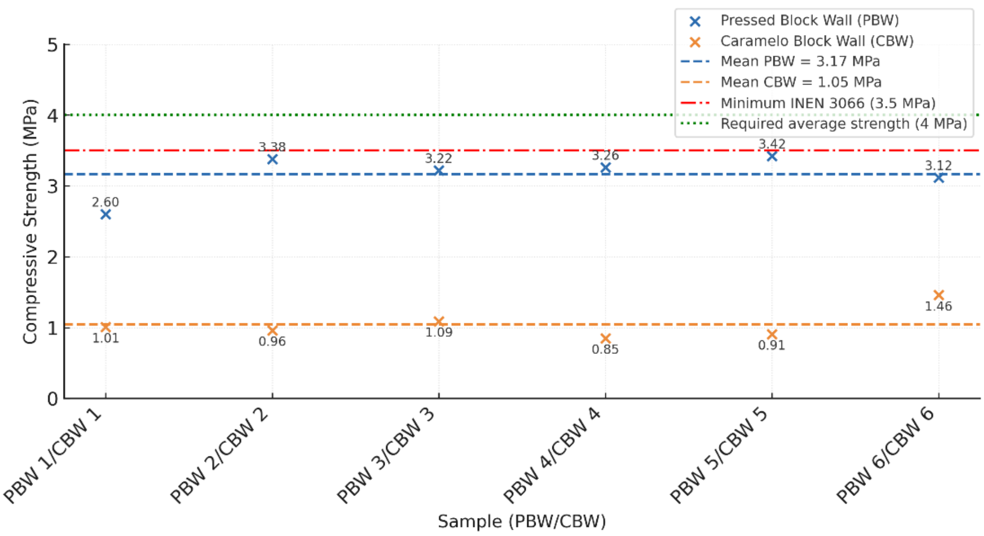


Fig. 23. Comparison of Compressive Strength of Walls between Pressed Blocks and Caramelo

Table 8. Height versus width correction factors for the compressive strength of masonry walls

h_m/a_m	1.30	1.50	2.00	2.50	3.00	4.00	5.00
Correction factor	0.75	0.86	1.00	1.04	1.07	1.15	1.22

Where h_m/a_m *Height-to-width aspect ratio of the low wall.*

3.2 Phase 3. Quantification of Materials and Costs

3.2.1 Masonry

During the construction of the three masonries, approximately 2 m2 each, a notable difference was observed in the final areas obtained. For the pressed block walls, the total constructed area was 6.62 m², obtaining an average area per masonry of 2,207 m² represented by Figure 24; while the caramelo block walls reached a smaller total area of 6,131 m², with an average area of 2,044 m² (Fig 25). It is evident that, with the same number of blocks (75), the pressed blocks generate 7.97% more area than the caramelo blocks (Figure 26).

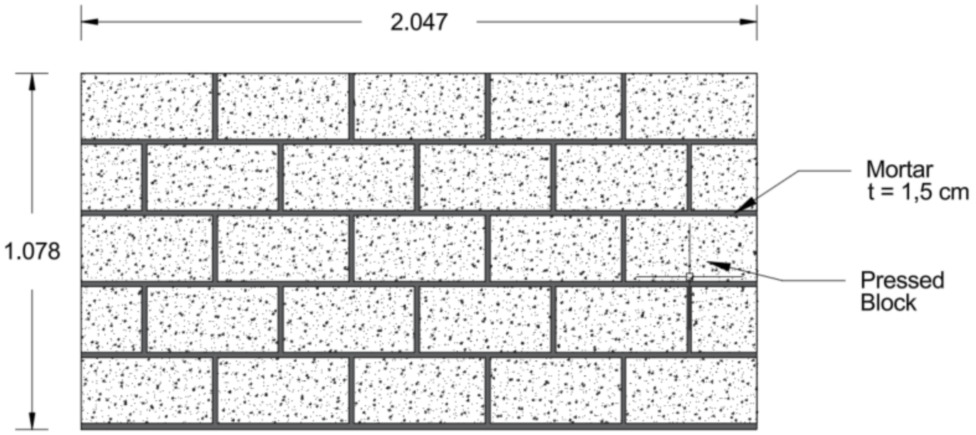


Fig. 24. Average dimensions of PP pressed block masonry

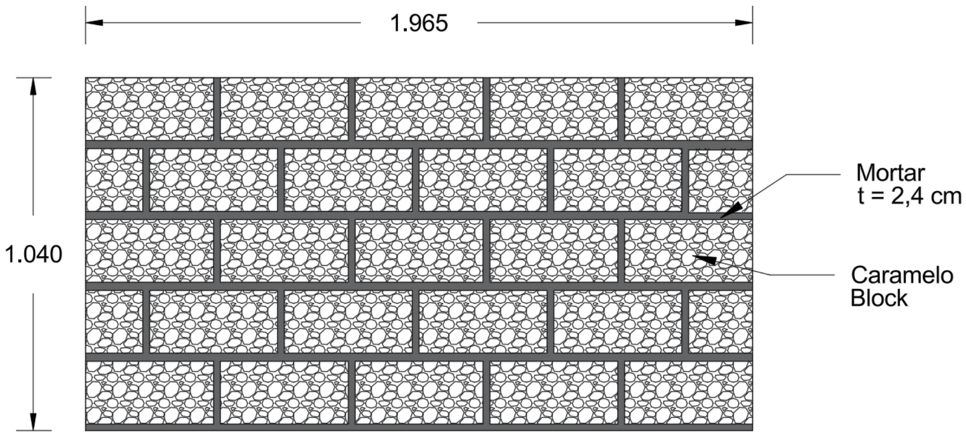


Fig. 25. Average dimensions of PC caramelo block masonry

Mortar consumption was higher in the case of caramelo blocks, confirming their lower efficiency on site due to their more porous texture and smaller, irregular dimensions, which result in thicker joints: 2.4 cm on average, compared to 1.5 cm in walls made of pressed blocks. In the three masonry units, this translated into a total mortar volume of 0.098 m^3 for pressed blocks and 0.135 m^3 for caramelo blocks, equivalent to 0.0148 m^3/m^2 and 0.0220 m^3/m^2, respectively. In relative terms, caramelo block masonry requires 37.76% more mortar volume than pressed block masonry. Consistently, the quantification of material consumption (cement, sand, and water) in mortar preparation shows that caramel block masonry consumes 38.23% more materials than pressed block masonry (Fig. 27).

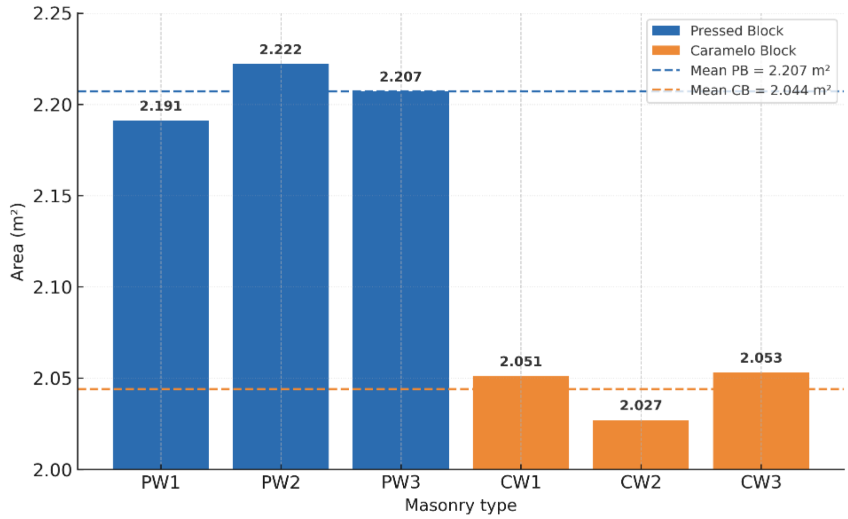


Fig. 26. Comparison of masonry areas between pressed block and caramelo block

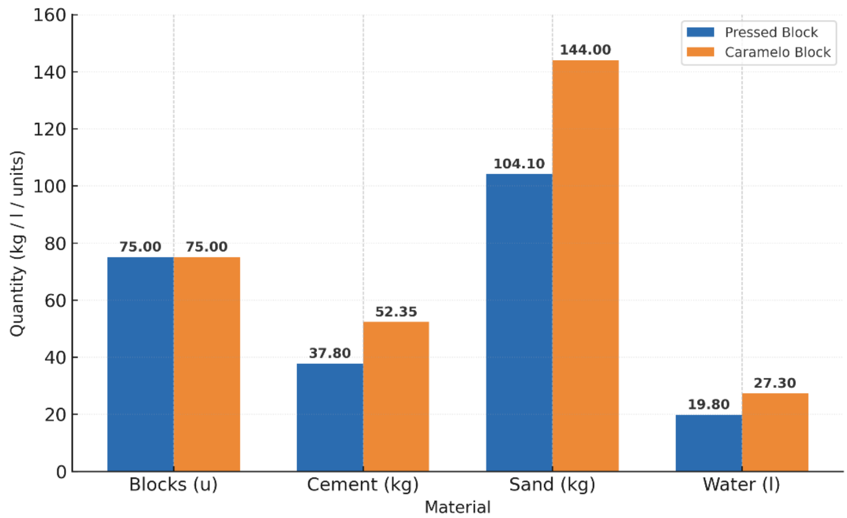


Fig. 27. Quantification of materials used in masonry

3.2.2 Plastering

Applied to both sides of the panels with mortar at a 1:4 ratio (cement:sand) and a thickness of 1.5 cm, higher material consumption was also evident in the caramelo block masonry. For the pressed block walls, a total area of 13.24 m² was covered, while for the caramelo block walls, the area was 12.262 m², with higher cement, sand, and water consumption in the latter, 25.12% higher (Fig 28). This shows that the porosity of the caramelo blocks requires more mortar to fill the voids and achieve the same plaster thickness as the pressed block.

3.2.3 Efficiency

Execution times for the three walls built with pressed blocks were 4.35 hours for masonry and 5.25 hours for plastering, whereas for the caramelo block walls they increased to 5.55 hours and 6.05 hours, respectively, reflecting the loss of productivity associated with their dimensional variability. The work was performed by a mason and a laborer under the supervision of a foreman, and hourly costs were calculated in accordance with the minimum wages established by law for the construction industry in Ecuador.

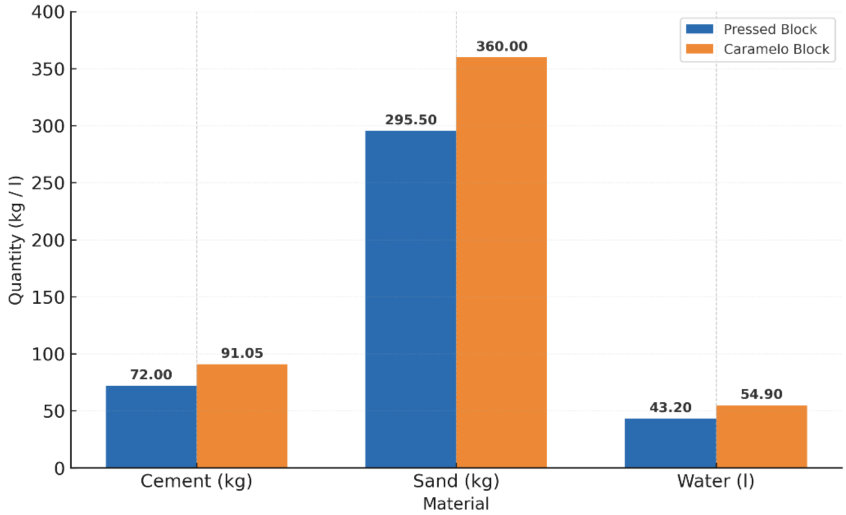


Fig. 28. Quantification of materials used in plastering

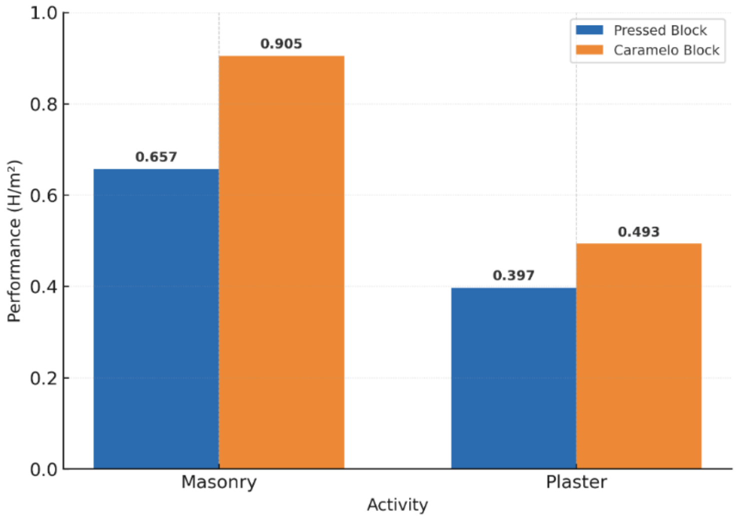


Fig. 29. Performance of masonry and plastering

These total times were then related to the effectively completed wall areas for masonry (6.62 m^2 for the pressed block walls and 6.131 m^2 for the caramelo block walls) and to the plastered areas, corresponding to both faces of each wall (13.24 m^2 for the pressed block panels and 12.262 m^2 for the caramelo block panels). This yielded labor productivities of 0.657 h/m^2 and 0.905 h/m^2 for masonry with pressed and caramelo blocks, respectively, and 0.397 h/m^2 and 0.493 h/m^2 for plastering. Based on these normalized values (h/m^2), it is observed that caramelo block masonry requires 37.75 % more time per square meter than pressed block masonry, and that plastering caramelo block panels takes 24.18 % longer per square meter, thereby increasing labor costs (Fig. 29).

3.2.4 Unit Price Analysis

In the unit price analysis, the cost of equipment corresponds to minor tools, including shovels, trowels, wooden boxes, and wheelbarrows used for the preparation, transport, and placement of mortar. According to standard budgeting practices for construction projects in Ecuador, the cost of these minor tools is estimated at 5% of the direct labor cost, since this equipment is used repeatedly in multiple work items and its individual depreciation per square meter is low. For this reason, in the breakdown of the Unit Prices (UPA) shown in Figure 30, the equipment cost share is relatively small compared to the material and labor costs. However, it is explicitly included to reflect the complete direct cost structure.

Finally, by integrating material consumption, execution times, equipment, labor, and material costs, unit price analyses (UPA) were prepared for the second quarter of 2025. For pressed block masonry, the unit price was USD 12.69/m^2 for masonry and USD 5.33/m^2 for plastering. For caramelo block masonry, the cost rose to USD 14.05/m^2 for masonry and USD 6.77/m^2 for plastering. Figure 30 shows the direct cost ratios for Equipment, Labor, and Materials for each executed item. These results show that, although the caramelo block has a lower acquisition price per unit, its construction performance is inferior, increasing the cost per square meter of masonry by 10.72% and 27.02% for plastering compared to pressed block.

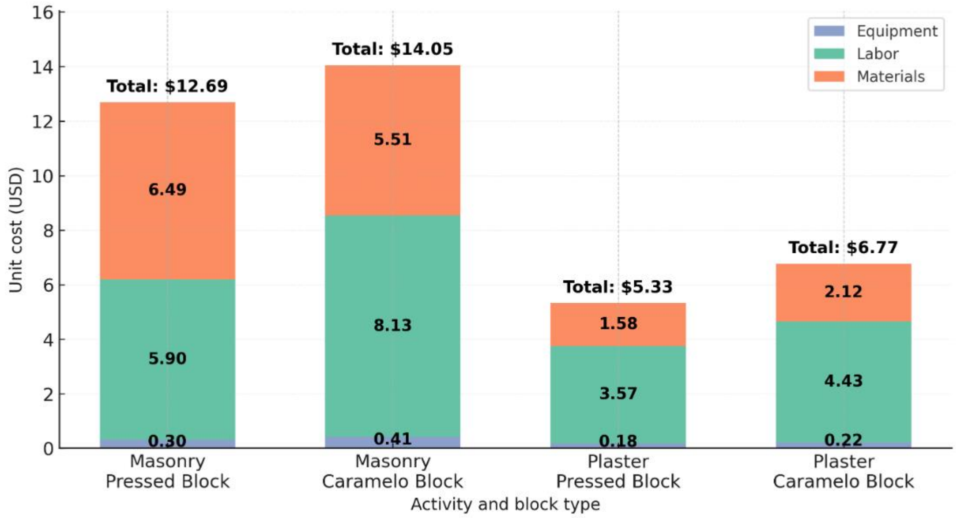


Fig. 30. Comparison of unit prices for masonry and plastering

4. Discussion

The results demonstrate that the quality of the manufacturing process decisively influences the physical-mechanical, structural, and economic behavior of non-structural infill masonry used in framed buildings. The comparison between the pressed block (PB) and caramelo block (CB) showed significant differences in strength, absorption, dimensional variability, and constructive efficiency, confirming the trends reported by [4] for artisanal blocks from Latin America.

The pressed block reached an average compressive strength of 2.39 MPa and a water absorption of 267.82 kg/m^3, while the caramelo block obtained 1.14 MPa and 343.38 kg/m^3, respectively. These differences confirm that only the PB partially complies with [16]for Class A blocks, meeting the absorption limit (<288 kg/m^3) but not the minimum strength (≥3.5 MPa) required for non-structural units. The CB, on the other hand, does not meet any regulatory parameter, reflecting its artisanal nature and the lack of compaction and curing control. The coefficient of variation in the strength of the CB (26.32%) was almost double that of the PB (13.55%), evidencing deficiencies in granulometric homogeneity and manufacturing processes. Equivalent results were reported by [2] and [9], who showed that a denser microstructure improves strength even under extreme conditions, such as fire exposure or biomass incorporation. However, the direct relationship between density, porosity, and strength was more clearly evidenced by [28], when analyzing blocks with industrial waste and establishing a positive correlation between compaction, reduced porosity, and mechanical performance. Complementarily, [29] showed that the use of unstable or high-absorption aggregates increases mechanical variability and accelerates surface degradation, consistent with the observations of this study. The inverse correlation between density and absorption (R^2 = 0.99) confirms that open porosity is the main factor determining the block's strength, in agreement with [30]and [8], who highlight that reducing voids and controlling curing are essential to improve durability and reduce concrete permeability.

The low walls built with pressed blocks reached an average strength of 3.17 MPa, while those made with caramelo blocks presented only 1.05 MPa, values corrected for slenderness according to [17]. In contrast, the average strengths of the individual blocks were 2.39 MPa for the pressed blocks and 1.14 MPa for the caramelo blocks. These differences, statistically significant ($p < 0.01$), are attributed to the manufacturing quality and the block-mortar adhesion. The structural efficiencies ($\eta = f'm / f'b$) were 1.33 for PB and 0.92 for CB, values higher than the 0.40–0.90 range reported by [31]. This result is explained by the low strength of the studied units, which magnifies the relative contribution of the mortar—of greater strength—to the assembly's behavior. Although the system analyzed by [13] corresponds to dry-stack and grouted masonry, that is, a different resistance mechanism, the values obtained here are also higher than those reported by said authors.

This behavior can also be attributed to the low slenderness of the walls ($h/t \approx 2.8$) and their small dimensions (24.6 × 41.5 × 15 cm in PB and 24.6 × 39.0 × 13.8 cm in CB), which increase stiffness and reduce instability during the test. The pressed block walls showed progressive crushing failures with good stress redistribution. In contrast, the caramelo block walls exhibited a conic-columnar failure mode with diagonal cracking and joint separation, attributable to the high absorption and surface roughness of the blocks. This pattern coincides with the findings of [5,12,32], who show that mechanical compatibility and block-mortar adhesion determine the post-peak stiffness and tension behavior of the masonry.

From a construction and economic perspective, the unit price analysis showed that pressed block masonry had a total cost of USD 12.69/m^2 compared to USD 14.05/m^2 for caramelo block (-9.7%). Regarding plastering, the difference was even greater: USD 5.33/m^2 for PB and USD 6.77/m^2 for CB (-21.3%). Overall, the finished wall cost was 13.45% lower with the pressed block system, despite its higher unit price. These savings are associated with a 27.4% reduction in construction time, lower joint thickness (1.5 cm vs. 2.4 cm), and a 32.7% reduction in mortar volume (0.0148 m^3/m^2 vs. 0.0220 m^3/m^2), resulting in approximately 30% lower cement, sand, and water consumption. These results are consistent with those reported by [19] and [20], who demonstrated that the greater dimensional accuracy and lower absorption of industrialized blocks optimize construction efficiency by reducing rework and material loss. In contrast, artisanal production generates units with high geometric and surface variability, which increases mortar use and on-site adjustment times. Consequently, the observed relationship between block quality, productivity, and overall cost validates the initial hypothesis: standardized blocks, although more expensive per unit, are more efficient when considering construction performance, material savings, and reduced environmental impacts associated with cement production.

Microstructure, density, and absorption analysis suggest that pressed blocks, with lower porosity and greater compactness, exhibit better performance against moisture-drying cycles and aggressive agents. According to [29] and [33], the reduction of interconnected porosity and the improvement of the paste-aggregate transition zone (ITZ) are determining factors in the service life of masonry by limiting the migration of water and salts and reducing the risk of disintegration due to expansive reactions. Consistently, [30] demonstrated that blocks with controlled aggregates and homogeneous compaction maintain their strength and microstructural stability after multiple freeze-thaw cycles, while materials with high porosity exhibit early cracking and mass loss. In the Ecuadorian context, where volcanic aggregates exhibit greater absorption and mineralogical variability, controlled industrial production becomes essential to ensure the durability, dimensional stability, and hygrothermal compatibility of nonstructural blocks. Although this research did not directly evaluate environmental sustainability, the results show that the industrialization and standardization of the process contribute indirectly to it by reducing mortar, cement, and energy waste during construction, in accordance with the principles of material efficiency and circularity described by [30].

Although the blocks studied are non-structural, their physical and geometric quality directly influences the overall behavior of the frame system. Walls constructed with pressed block exhibit a more uniform interaction with the structural frame, reducing cracking due to deformation incompatibility and improving energy dissipation under lateral loads. This behavior is consistent with the results of [14,34] and [5], who demonstrated that the homogeneity of the enclosure and the quality of the block-mortar interface increase initial stiffness and post-cracking recovery capacity. In contrast, walls made with caramelo block, with lower density and regularity, tend to develop early diagonal cracks and joint debonding, reducing their contribution to structural damping. From a technical and economic perspective, adopting standardized, industrialized blocks constitutes a comprehensive strategy for quality, durability, and sustainability by improving structural compatibility and reducing maintenance and repair costs. The results of this research provide unprecedented experimental evidence for the central Sierra of Ecuador and reinforce the need to strengthen quality control mechanisms and compliance with [16], in local production plants, as an essential requirement for the safe seismic design of framed buildings with infill masonry.

Overall, the results confirm that the mechanical, structural, and economic efficiency of nonstructural masonry depends directly on the type and quality of the concrete block. The pressed block, by partially meeting regulatory specifications, exhibits more stable strength, lower absorption, better mortar adhesion, and a significant reduction in total construction costs. In contrast, the artisanal caramelo block shows high variability and excessive material consumption. These findings confirm the importance of promoting controlled industrialization and the rigorous application of Ecuadorian standards to improve the quality, durability, and sustainability of enclosures in framed buildings in the Andean region.

4.1 Research Limitations

Despite the experimental scope and representativeness obtained, this research presents certain limitations that must be considered when interpreting the results. The tests were conducted on a laboratory scale and with a limited number of samples, which restricts direct extrapolation to industrial production. Furthermore, the tests were carried out under controlled environmental conditions, without considering the effects of prolonged exposure to humidity, temperature, or aggressive agents. Dynamic properties or parameters related to direct seismic performance, such as the modulus of elasticity and damping, were not evaluated. The carbon footprint or environmental impacts of unit manufacturing were not quantified, although the results suggest a favorable relationship between industrialization and sustainability. Finally, the results are limited to the geographical and productive context of the Latacunga canton, so their external validity must be verified in other regions and with different aggregate conditions and curing processes. Future studies should include advanced microstructural analysis, accelerated aging cycles, and full-scale evaluations to consolidate physical, mechanical, and environmental performance models for nonstructural masonry in Ecuador.

It is worth noting that [16] and [17] do not require experimental determination of the percentage of voids for perforated units. Therefore, this parameter was not measured in this study and is considered beyond its scope. At the same time, the classification of the blocks as lightweight perforated units is based on their geometry and bulk density.

5. Conclusions

The results of this research confirm that the quality of the concrete block manufacturing process decisively influences the physical-mechanical, constructional, and economic performance of nonstructural masonry used in frame buildings. The pressed blocks showed more stable, homogeneous properties, whereas the caramelo blocks showed greater variability due to artisanal production, which directly affects the durability and safety of the enclosures.

Both types of blocks are classified as lightweight according to [16]; however, these differences confirm that, while the pressed block (PB) meets the absorption limit for Class A units (<288 kg/m^3), neither type reached the minimum strength of 3.5 MPa required by the same standard for blocks for nonstructural use (Class B). This behavior demonstrates the direct influence of the compactness and homogeneity of the manufacturing process on regulatory compliance and on the material's structural response. The strength of the masonry walls followed the same trend: those built with pressed blocks reached 3.17 MPa, compared to 1.04 MPa for those built with caramelo blocks. This result confirms that the quality of the basic unit determines the overall strength of the masonry, consistent with international studies that associate block-mortar adhesion and geometric uniformity with stiffness and load-bearing capacity. The identified failure modes—progressive crushing and diagonal cracking accompanied by joint separation—highlight the role of porosity and water absorption in governing stress redistribution and cohesion loss in masonry elements.

From a construction perspective, the pressed blocks offered superior performance, reducing construction time by 27.4% and the volume of mortar and plaster used by 32.7%. The dimensional regularity, the smaller joint thickness (1.5 cm versus 2.4 cm), and the low absorption of the pressed blocks reduced material waste and the need for corrections, optimizing personnel efficiency and improving the surface quality of the finished walls.

The economic analysis showed that although the caramelo block had a lower unit cost per piece, its total application cost was higher (USD 14.05/m^2 for masonry and USD 6.77/m^2 for plaster) than that of the pressed blocks (USD 12.69/m^2 and USD 5.33/m^2, respectively). Overall, the pressed block system was 13.45% more economical per square meter of finished wall, confirming that better initial quality translates into overall savings in materials, time, and resources.

In terms of durability, the pressed block exhibits greater density and compactness, which enables better performance under humidity-drying cycles, aggressive agents, and thermal variations. In contrast, the more porous structure of the caramelo block limits its use to indoor or low-exposure environments. This contrast reinforces the need to improve curing and aggregate selection processes in artisanal production, as well as to implement continuous technical controls in manufacturing plants. Overall, the results show that pressed block is the most suitable alternative for infill masonry in framed buildings in the Andean region, balancing quality, safety, productivity, and sustainability. Its use contributes to reducing waste, optimizing resources, and extending the useful life of buildings, aligning with internationally promoted material efficiency and sustainable construction policies.

Finally, the need to strengthen quality control mechanisms and strictly enforce [16] In local production plants, priority strategies are reinforced to improve the quality of the housing stock, reduce economic losses due to construction inefficiencies, and mitigate vulnerabilities in seismic zones such as the central Sierra of Ecuador. Future studies should incorporate dynamic analysis, accelerated durability assessment, and carbon footprint calculation to consolidate comprehensive models that link material quality, sustainability, and structural performance in Ecuadorian construction.

References

[1] Álvarez-Pérez J, Mesa-Lavista M, Chávez-Gómez JH, Fajardo-San Miguel G, Carpio-Santamaría FA, García-Cedeño R. Analysis of behavior and uniaxial compression failure modes in ungrouted hollow concrete block masonry and their implication in design expressions. Journal of Building Engineering 2024;98:111048. https://doi.org/10.1016/J.JOBE.2024.111048.

[2] Medeiros WA, Parsekian GA, Moreno AL. Residual mechanical properties of hollow concrete blocks with different aggregate types after exposure to high temperatures. Constr Build Mater 2023;377:131085. https://doi.org/10.1016/J.CONBUILDMAT.2023.131085.

[3] Ozmen HB, Inel M. Effect of concrete strength and detailing properties on seismic damage for RC structures. Research & Design 2024;1:1–11. https://doi.org/10.17515/REDE2024-005EN1124RS.

[4] Escamirosa Montalvo LF, Molina Narváez N. Análisis de la resistencia a la compresión de bloques de concreto usados en la construcción de viviendas en la ciudad de Tuxtla Gutiérrez, Chiapas. Revista Espacio I+D Innovación Más Desarrollo 2022;XI:34–47. https://doi.org/10.31644/IMASD.29.2022.a03.

[5] Chávez-Gómez JH, Álvarez-Pérez J, Mesa-Lavista M, García-Cedeño R, Carpio-Santamaría FA, Fajardo-San-Miguel G, et al. Experimental dataset of masonry prisms with hollow concrete blocks. Data Brief 2024;53:110207. https://doi.org/10.1016/J.DIB.2024.110207 .

[6] Ozmen HB, Tanrıverdi B. Concrete paradox: Economic importance, environmental impacts, and the sustainability of concrete material. Research & Design 2025;2:66–84. https://doi.org/10.17515/REDE2025-008EN0801RS.

[7] Jeon JH, Son YH, Kim TJ, Jo SB. Engineering performances of permeable concrete blocks using oyster shell, bottom ash, and biochar. Constr Build Mater 2024;440:137374. https://doi.org/10.1016/J.CONBUILDMAT.2024.137374.

[8] Sim Y, Oh S, Song C, Lee SC, Hong G. Utilization of steel slag for sustainable concrete blocks: Laboratory study on water absorption, flexural strength, carbon dioxide capture, and volumetric expansion. Journal of Building Engineering 2025;111:113335. https://doi.org/10.1016/J.JOBE.2025.113335.

[9] Hwalla J, Al-Mardeai S, Al-Zuhair S, Moheimani N, Hamza W, El-Maaddawy T, et al. Properties and microstructure of concrete masonry blocks incorporating chrysotila carterae microalgal biomass. Journal of Building Engineering 2025;111:113585. https://doi.org/10.1016/J.JOBE.2025.113585.
[10] Azouggagh M, El Aabbas M, Bouchikhi A, Farkach Y, Safhi AEM, Assoudi R, et al. Hollow concrete blocks incorporating a phase change material: thermal and mechanical behaviours analysis. Thermal Science and Engineering Progress 2025;64:103841. https://doi.org/10.1016/J.TSEP.2025.103841.
[11] Do DD, Luong NT, Tran TT, Bui HM. Utilization of waste materials for ultra-lightweight and thermal insulating concrete blocks. Sustainable Chemistry One World 2025;5:100039. https://doi.org/10.1016/J.SCOWO.2024.100039.
[12] Mesa-Lavista M, Romo-Letechipía P, Álvarez-Pérez J, González-Alcorta R, Chávez-Gómez JH, Fajardo-San Miguel G. Shear strength dataset of hollow concrete block masonry with different mortar bedding. Data Brief 2024;57:111144. https://doi.org/10.1016/J.DIB.2024.111144.
[13] Sathurshan M, Derakhshan H, Thamboo J, Gill J, Inglis C, Zahra T. Compressive strength in grouted dry-stack concrete block masonry: Experimental and analytical predictions. Constr Build Mater 2025;467:140411. https://doi.org/10.1016/J.CONBUILDMAT.2025.140411.
[14] Zhang Z, Dong Y, Sun H, Yang H, Sun M, Wang R, et al. Seismic behavior and repairability of new composite concrete block wall with distributed slipping damage. Structures 2025;75:108683. https://doi.org/10.1016/J.ISTRUC.2025.108683.
[15] INEC. Estadísticas de Edificaciones (ESED) Permisos de construcción, I Trimestre 2025. 2025.
[16] NTE INEN 3066. Bloques De Hormigón. Requisitos Y Métodos De Ensayo. 2016.
[17] NTE INEN 3153. Muretes De Mampostería Elaborados En Laboratorio. Determinación De La Resistencia A La Compresión. 2020.
[18] Nuñez P, Palacios F, Taranto E, Armijos S. Elaboración Y Caracterización De Un Material Compuesto Con Polietileno De Tereftalato Para La Fabricación De Bloques. Perfiles 2023;1:52–62. https://doi.org/10.47187/perf.v1i29.206.
[19] Herrera-González J, Ortiz-Rabell G, Xilotl-Domínguez J, Ojeda-Farias O, Flores-Vivian I, Vázquez-Leal F, et al. Use of waste material from the chemical industry for the production of low-strength concrete hollow blocks. Sustainable Materials and Technologies 2024;40:e00870. https://doi.org/10.1016/J.SUSMAT.2024.E00870.
[20] Musab Manzoor K, EhtishamUddin S. Utilization of a mixture of waste plastic materials and granite particles as a partial replacement of coarse aggregate in concrete blocks. Mater Today Proc 2023. https://doi.org/10.1016/J.MATPR.2023.05.095.
[21] NTE INEN 856. Áridos. Determinación De La Densidad, Densidad Relativa (Gravedad Específica) Y Absorción Del Árido Fino. 2010.
[22] NTE INEN 2380. Cementos Hidráulicos. Requisitos De Desempeño Para Cemenos Hidráulicos. 2011.
[23] NTE INEN 156. Cemento Hidráulico. Determinación De La Densidad. 2009.
[24] NTE INEN 157. Cemento Hidráulico. Determinación De La Consistencia Normal. Método De Vicat. 2009.
[25] NTE INEN 158. Cemento Hidráulico. Determinación Del Tiempo De Fraguado. Método Del Vicat. 2009.
[26] NTE INEN 2502. Cemento Hidráulico. Determinación Del Flujo En Morteros. 2009.
[27] NTE INEN 488. Cemento Hidráulico. Detrerminación De La Resistencia A La Compresión De Morteros De 50 mm DE ARISTA. 2009.
[28] Kuoribo E, Shokry H, Mahmoud H. Attaining material circularity in recycled construction waste to produce sustainable concrete blocks for residential building applications. Journal of Building Engineering 2024;96:110503. https://doi.org/10.1016/J.JOBE.2024.110503.
[29] Brough C, Staniforth B, Garner C, Garside R, Colville R, Strongman J, et al. High risk concrete blocks from County Donegal: The geology of defective aggregate and the wider implications. Constr Build Mater 2023;408:133404. https://doi.org/10.1016/J.CONBUILDMAT.2023.133404.
[30] Qi Y, Wang Q, Li Z, Xiong Y, Wang C. Durability and microstructure of bulk solid waste recycled concrete load-bearing block under freeze-thaw cycles. Journal of Building Engineering 2025;112:113881. https://doi.org/10.1016/J.JOBE.2025.113881.
[31] Zahra T, Thamboo J, Asad M. Compressive strength and deformation characteristics of concrete block masonry made with different mortars, blocks and mortar beddings types. Journal of Building Engineering 2021;38:102213. https://doi.org/10.1016/J.JOBE.2021.102213.
[32] Gouda O, Hassanein A, Youssef T, Galal K. Stress-Strain Behaviour of Masonry Prisms Constructed with Glass Fibre-Reinforced Grout. Constr Build Mater 2021;267:120984. https://doi.org/10.1016/J.CONBUILDMAT.2020.120984.
[33] Ghiassi B, Lourenço PB. Long-term Performance and Durability of Masonry Structures: Degradation Mechanisms, Health Monitoring and Service Life Design. Elsevier; 2018.
[34] Zhang Z, Dong Y, Zhang S, Yang J, Chen C, Song X, et al. Seismic performance of new composite concrete block bearing wall with good sound insulation. Constr Build Mater 2025;481:141648. https://doi.org/10.1016/J.CONBUILDMAT.2025.141648.