

# Solid Concrete Bricks with the Incorporation of Demolition Waste Application under Peruvian Standards such as NTP 399.601

Ccori Siello Vega Neyra\*, Sleyther Arturo De La Cruz Vega, Cristian Milton Mendoza Flores

Department of Engineering, National University of Barranca, Perú

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**Abstract** Solid concrete brick is a commonly used material in construction, although it often presents some problems such as low strength, cracking, and dimensional fluctuations that do not always comply with current regulations. The purpose of this study was to analyze the physical and mechanical properties of solid concrete bricks made with demolition waste (DW), incorporated in different proportions of 0%, 5%, 10%, 15%, and 20% of fine aggregate. An applied methodology, experimental design, and a quantitative approach were used. The population consisted of all solid concrete brick units with DW, while the sample consisted of 110 specimens selected in accordance with Peruvian Technical Standard NTP 399.601. These bricks were subjected to compressive strength, absorption, and dimensional variation tests. The results obtained show that all dosages with demolition waste improved compressive strength, with 5% DW standing out, reaching an average strength of 24.6 MPa (+12.86%). This same dosage showed a maximum absorption of 8.4% (+5.00%) and a minimum dimensional variation, with values of 1.82% in length, 3.64% in width, and 0.00% in thickness, demonstrating that the incorporation of demolition waste not only increases concrete strength but also maintains absorption and dimensional variation within acceptable ranges according to regulations. It is concluded that demolition waste has a significant impact on the physical and mechanical properties of solid concrete bricks, optimizing their

performance and offering a viable alternative for their production.

**Keywords** Concrete, Demolition, Bricks, Waste, Housing

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## 1. Introduction

Construction is one of the most important economic activities worldwide, due to its fundamental role in shaping infrastructure and creating urban spaces. However, despite its benefits, this industry also stands as one of the main generators of solid waste, which poses a serious environmental concern when not properly managed.

Over the years, bricks have remained a key component in the construction of buildings, both in public and private projects. Nevertheless, their physical and mechanical properties often present notable limitations that compromise the quality and longevity of structures. Among the most common issues found in concrete bricks are low compressive strength, irregular dimensions, and high-water absorption. As highlighted in [1], many brick kilns fail to meet basic quality standards, largely due to the growing pressure of demand in the construction sector. Insufficient compaction during mix preparation weakens the material's strength [2], while non-technical manufacturing practices

cause dimensional inconsistencies and increased porosity - ultimately diminishing mortar adhesion.

At the global level, the generation of demolition waste (DW) has surged alongside urban expansion. According to Andrea et al. [3], the absence of adequate regulations for its final disposal has led to uncontrolled accumulation of debris, which in turn degrades soil quality, contaminates water sources, and endangers public health. In Latin America, the situation is even more complex due to the lack of specialized sites for waste management. In many urban areas, demolition waste is dumped in informal landfills, contributing to environmental deterioration and social problems [4].

In the case of Peru, demolition waste management remains insufficient. In cities like Lima, large volumes of construction debris are still disposed of on public streets and empty lots, exacerbating environmental pollution [5]. At the same time, the widespread practice of self-construction has exposed flaws in the quality of materials used, particularly concrete bricks. Similarly, the city of Barranca faces a notable accumulation of construction debris along cliffs and in peri-urban areas, altering the natural landscape, compromising soil stability, and limiting the feasibility of future development [6].

In recent years, numerous researchers have explored the use of demolition waste as a viable and sustainable alternative for brick manufacturing. Some have demonstrated that incorporating recycled aggregates into ceramic bricks is feasible without compromising their strength, and has even achieved improvements in the final product's weight [7]. They also experimented with a combination of demolition waste and industrial by-products, obtaining bricks with satisfactory thermal performance and technical properties that meet established standards [8]. Similarly, other authors focused on the reuse of masonry debris in compressed earth bricks and found that, in addition to maintaining adequate structural performance, this approach contributes positively to the reduction of the environmental impact of construction [9]. Data also showed that finely crushed concrete waste can improve the compaction and uniformity of bricks, resulting in a more consistent and durable product [10].

Faced with these challenges, the objective of this research is to assess the impact of incorporating demolition waste on the physical and mechanical properties of solid concrete bricks. To achieve this, the study explores five substitution ratios (0%, 5%, 10%, 15%, and 20%) of DW as a replacement for fine aggregate. The methodology follows an experimental design with a quantitative approach, aligned with Peruvian technical standards. The performance of the bricks was evaluated through tests such as compressive strength, water absorption, and dimensional variation.

The central research question guiding this study is: What

is the effect of different demolition waste replacement percentages on the physical-mechanical properties of solid concrete bricks? The aim is to generate reliable data that supports decision-making within the construction industry.

From an environmental perspective, reusing demolition waste helps reduce the amount of material sent to landfills while decreasing the extraction of natural aggregates, thereby fostering a more sustainable cycle in construction practices. On the scientific front, this research provides evidence on the viability of using recycled waste as an alternative to conventional materials, paving the way for future investigations.

Socially, the use of recycled construction materials contributes to cleaner public spaces and improved urban environments, ultimately enhancing the quality of life for local populations. Economically, incorporating demolition waste into brick production reduces manufacturing costs by limiting the need for virgin aggregates and lowering expenses associated with waste disposal.

Theoretically, this study adds to the growing body of knowledge on sustainable construction by demonstrating how recycled materials can be effectively repurposed in civil engineering. It helps close gaps in current understanding regarding the use of demolition waste in brick production and promotes innovation in the development of environmentally responsible construction materials.

## 2. Materials and Methods

### 2.1. Type of Research

The research is applied, as it seeks to modify a real-life problem through the use of knowledge to offer scientific solutions [11], focusing on evaluating concrete bricks made from demolition waste, thus validating their physical-mechanical properties through laboratory tests [12].

### 2.2. Research Design

The design is quasi-experimental, as it allows testing a causal hypothesis by manipulating an independent variable in contexts where the study groups could not be randomly assigned [13], and the influence of waste on the characteristics of concrete bricks, such as compressive strength, dimensional variation, and absorption, will be evaluated.

### 2.3. Research Approach

The approach is quantitative, aimed at obtaining numerical results through the aforementioned tests [14]. The results will be analyzed according to Peruvian Technical Standard NTP 399.604.

## 2.4. Population and Sample

The population considered consists of units of solid concrete bricks made from demolition waste. For the sample, 110 brick units were selected, to which demolition waste (DW) was incorporated in different percentages. The criterion for defining these percentages was to obtain a wider range of analysis, in order to observe differences on a larger scale [15], using percentages of 0%, 5%, 10%, 15% and 20% DW.

## 2.5. Techniques to Be Employed

The sheet will provide the necessary guidelines to perform laboratory evaluations, collect samples and ensure proper data collection, with the most relevant aspects being compressive strength, dimensional variation, and absorption.

## 2.6. Investigation Procedure

The procurement of materials for this research focused on three key components. Demolition waste was collected from landfills in Barranca, specifically from La Bandurria, which is an accessible and free site. From this waste, simple concrete waste such as pavements and floors was selected, and non-useful materials such as iron, wood, glass, and plastic were separated. The cement used was SOL cement, purchased from the hardware store El Inge del Norte Chico, and the coarse sand was obtained from the company Purito Ripio S.A.C., located near the National University of Barranca. The processing of the materials included crushing the demolition waste with a 2 kg hammer to reduce its size. This process resulted in particles of different sizes, which were then sieved using a 4.76 mm sieve to obtain the final aggregate.

Table 1 presents a chemical analysis of the waste, carried out using an X-ray fluorescence spectrometer, which revealed high concentrations of 36.839% calcium, 29.509% silicon, 14.126% aluminum, and 10.202% iron. These elements are commonly found in conventional coarse sand and cement, indicating that the demolition waste is suitable for incorporation into the production of concrete bricks. As shown in the table, the waste does not contain lead, asbestos, or other contaminants that could pose health risks to users. Additionally, it is important to note that during the installation process, the bricks are coated with a layer of plaster or mortar, which fully encapsulates the units, providing additional protection against potential health hazards and environmental impacts.

**Table 1.** Chemical elements and oxides present in demolition waste

Element	Result (%)	Oxide	Result (%)
Calcium (Ca)	36.839	Silicon Oxide (SiO <sub>2</sub> )	36.852
Silicon (Si)	29.509	Calcium Oxide (CaO)	30.089
Aluminum (Al)	14.126	Aluminum Oxide (Al <sub>2</sub> O <sub>3</sub> )	15.581
Iron (Fe)	10.202	Iron Oxide (Fe <sub>2</sub> O <sub>3</sub> )	8.515
Magnesium (Mg)	4.477	Magnesium Oxide (MgO)	4.334
Potassium (K)	2.069	Sulfur Oxide (SO <sub>3</sub> )	1.748
Sulfur (S)	1.199	Potassium Oxide (K <sub>2</sub> O)	1.455
Titanium (Ti)	1.066	Titanium Oxide (TiO <sub>2</sub> )	1.038
Manganese (Mn)	0.218	Manganese Oxide (MnO)	0.164
Strontium (Sr)	0.197	Strontium Oxide (SrO)	0.136
Zirconium (Zr)	0.057	Zirconium Oxide (ZrO <sub>2</sub> )	0.045
Vanadium (V)	0.041	Vanadium Oxide (V <sub>2</sub> O <sub>5</sub> )	0.043

The solid bricks were made following the indications of the ACI 211 committee, using metal molds with dimensions of 11 x 22 x 9 cm, and were manufactured by adding percentages of demolition waste of 5%, 10%, 15% and 20% DW, in order to evaluate their performance in the concrete mix.

Laboratory tests were carried out to evaluate the quality of the specimens. These included the dimensional variation test, measuring the dimensions of each brick using a millimetric ruler, the water absorption test, immersing in water for 24 hours, drying and weighing the samples. Finally, in the compressive strength test, the bricks were subjected to pressure until they broke, to evaluate their capacity to withstand loads.

## 3. Results

Tests were carried out to evaluate the properties of the solid concrete bricks in terms of compressive strength, absorption, and dimensional variation, following the corresponding standards NTP 339.604 and ASTM guidelines (C 140-08, C 67 and C 62). In the compressive strength test, the compressive strength in MPa and the stresses applied to the samples were determined, using 6 specimens for each dosage of demolition waste (0%, 5%, 10%, 15% and 20%). In the absorption test, the percentage of water absorption in the bricks was evaluated, using 6 specimens for each dosage of demolition waste. Finally, in the dimensional variation test, the dimensional changes of the samples were determined, using 10 specimens for each dosage of demolition waste. The results obtained from these tests are presented below.

**3.1. Compressive Strength**

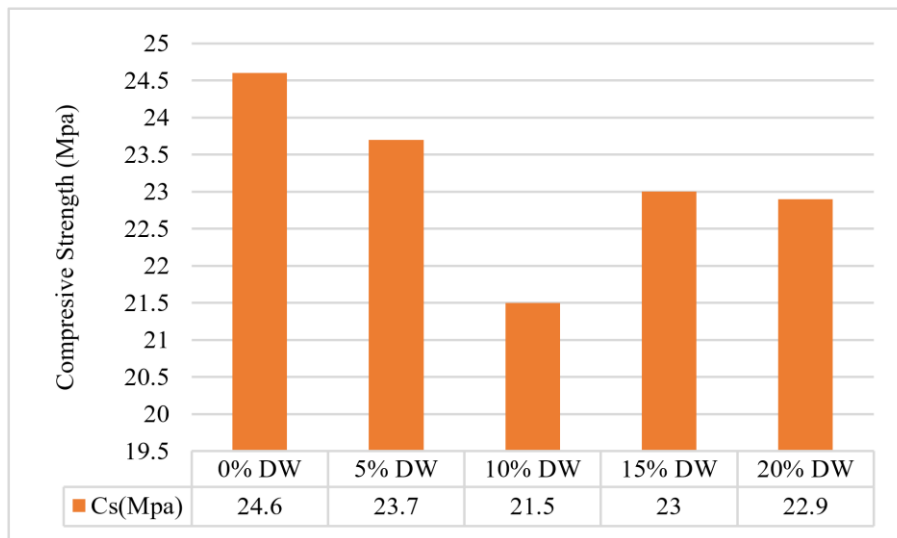
Table 2 presents the compressive strength values of the standard sample and those replaced with 5%, 10%, 15%, and 20% demolition waste (DW), expressed in megapascals (MPa), with results of 24.6 MPa, 23.7 MPa, 21.5 MPa, 23.0 MPa, and 22.9 MPa, respectively. These values all exceed the minimum strength required for solid concrete bricks. The average compressive strength across all samples was 23.14 MPa, with a standard deviation of 1.14 MPa. Additionally, the 95% confidence interval for the mean strength ranged from 21.72 MPa to 24.56 MPa, indicating a statistically reliable performance within the acceptable structural range. These results demonstrate that the DW-containing samples achieved exceeded 100% of the minimum required strength, validating their effectiveness for brick production. Among the tested

dosages, incorporating 5% DW translates into greater reliability, reaching 23.7 MPa (+12.86%) and reflecting improved structural performance. The strength results suggest that the demolition waste particles possess characteristics comparable to those of coarse sand, as their inclusion does not significantly alter the mechanical behavior of the bricks, remaining within safe and acceptable performance parameters.

Figure 1 presents the average compressive strengths for each of the demolition waste (DW) dosages, and all percentages analyzed exceed the minimum strength required for classification as type 24 brick (21 MPa) according to NTP 399.601 [16]. It can be seen that the incorporation of 5% DW results in one of the best strengths, reaching an average of 23.7 MPa, indicating that this dosage has a positive impact on the strength of the concrete.

**Table 2.** Compressive strength of the solid bricks studied

Dosage	Compressive Strength (MPa)	Minimum required strength (MPa)	% Strength
0% of DW	24.6	21	117.22%
5% of DW	23.7		112.86%
10% of DW	21.5		102.54%
15% of DW	23.0		109.52%
20% of DW	22.9		109.05%



**Figure 1.** Average compressive strength for each dosage executed

**Table 3.** Water absorption of the studied samples

Dosage	Absorption (%)	Admitted (%)	% Achieved
0% of DW	8.1	8	101.67%
5% of DW	8.4		105.00%
10% of DW	8.6		107.92%
15% of DW	8.1		101.25%
20% of DW	8.5		105.63%

### 3.2. Absorption

Table 3 presents the resulting absorption for the standard samples (0%, 5%, 10%, 15%, and 20% of DW), with average values of 8.1%, 8.4%, 8.6%, 8.1%, and 8.5%, respectively. These values are higher than those of the standard sample and the previously analyzed dosage. The results indicate greater absorption; therefore, within the dosages, incorporating 5% and 15% DW translates into more favorable results since they do not increase absorption significantly compared to other dosages. The overall average absorption was 8.34%, with a standard deviation of 0.23% and a 95% confidence interval ranging from 8.05% to 8.63%. It is clear that demolition waste has absorption characteristics similar to coarse sand, so there is little variation when used in solid brick. This is very important because, since brick does not absorb much water, it does not harm the mortar mix when building walls.

Figure 2 presents the average absorptions for each dosage. It is observed that the standard sample, with 0% DW, shows the lowest absorption, thus establishing a reference standard for the other dosages. Furthermore, it is highlighted that the incorporation of 15% DW resulted in the second lowest absorption, with an average of 8.1%. This dosage is followed by the 5% DW, which reached an average of 8.4%. These results suggest that both dosages have a positive impact on absorption.

### 3.3. Dimensional Variation

Table 4 presents the length, width, and thickness measurements of the unaltered and replaced samples, obtaining average values of 224.4 mm in length, 114.2 mm in width, and 90.8 mm in thickness, with standard deviations of 0.55 mm, 0.84 mm, and 0.45 mm, respectively. These dimensions are within tolerable parameters, since they do not exceed the margin of  $\pm 3.2$

mm. The 95% confidence intervals for these measurements are [223.72, 225.08] mm for length, [113.16, 115.24] mm for width, and [90.25, 91.36] mm for thickness, confirming the consistency of the dimensional values. The samples with 5% demolition waste had average values of 224 mm in length, 114 mm in width, and 90 mm in thickness. The incorporation of 5% DW translates into more favorable results since this dimensional variation is permissible. The demolition waste has a larger particle size than coarse sand, causing small increases in the length, height, and width of the solid bricks. However, this increase is within the permissible limits, so solid concrete bricks can be used normally.

Figure 3 presents the average dimensional variations for each of the demolition waste (DW) dosages as percentages. It is observed that, in comparison to the standard sample, the sample with 5% DW presents the lowest percentage variations, with an increase of only 1.82% in length, 3.64% in width, and 0.00% in thickness in relation to the design dimensions. This suggests that the incorporation of 5% DW results in the lowest percentage deviations from the ideal dimensions, indicating good dimensional stability, which underscores the effectiveness of the 5% proportion in maintaining the dimensional accuracy of solid concrete brick.

### 3.4. Durability Analysis

Masonry units should present a solid and compact nature, which enhances their resistance to compression, surface abrasion, and water absorption. In line with this, various authors have reported, according to Table 4, good strength levels and, consequently, adequate durability in the analyzed units. Furthermore, it is worth noting that, when installed in walls and covered with mortar and plaster layers, these units are protected against environmental and moisture-related effects.

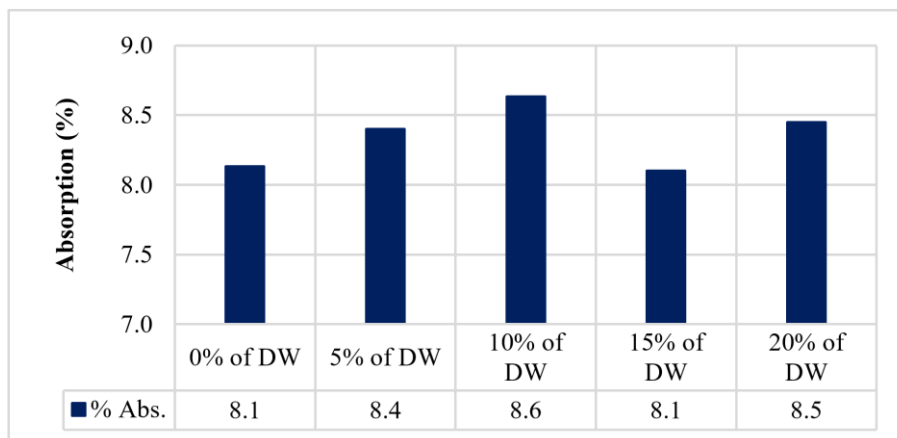
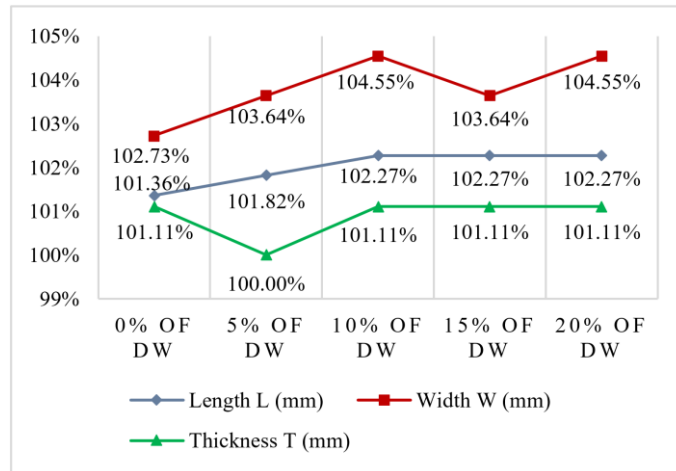


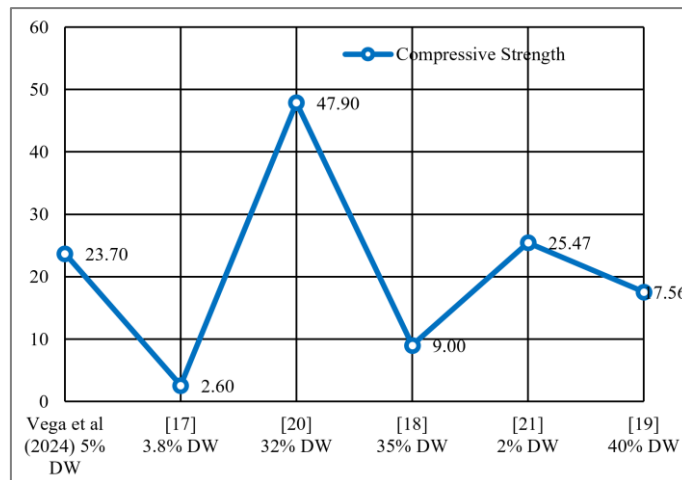
Figure 2. Average absorption for each dosage executed

**Table 4.** Dimensional variation tests applied

Dosage	Dim. (mm)	Meas. (mm)	Add. Meas. (mm)	% Meas.
0% of DW	Length (L)	223	3	101.36%
	Width (W)	113	3	102.73%
	Thickness (T)	91	1	101.11%
5% of DW	Length (L)	224	4	101.82%
	Width (W)	114	4	103.64%
	Thickness (T)	90	0	100.00%
10% of DW	Length (L)	225	5	102.27%
	Width (W)	115	5	104.55%
	Thickness (T)	91	1	101.11%
15% of DW	Length (L)	225	5	102.27%
	Width (W)	114	4	103.64%
	Thickness (T)	91	1	101.11%
20% of DW	Length (L)	225	5	102.27%
	Width (W)	115	5	104.55%
	Thickness (T)	91	1	101.11%



**Figure 3.** Percentage variation of dimensional variation for each dosage executed



**Figure 4.** Compressive strength of solid concrete bricks according to different authors

### 4. Discussion

Regarding the compressive strength of solid bricks, the highest strength value was achieved by incorporating a 5% dosage of demolition waste, reaching an average of 23.7 MPa, thus exceeding the minimum strength for this type of brick of 21 MPa and the rest of the dosages executed in the study. In contrast, Patricia et al. [17] used a dosage of 3.8% demolition waste and obtained a much lower compressive strength value of only 2.60 MPa, also Mandefrot [18] by adding 35% waste, reached a strength of 9.00 MPa, while Jhuston [19] reached a median compressive strength of 17.56 MPa by incorporating 40% demolition waste. The authors who agree are Rafael et al. [20], who incorporated 32% waste and achieved the highest recorded strength, with 47.90 MPa, and Han-Dong and Liujun [21], who obtained 25.47 MPa by incorporating a minimum amount of 2% waste. With the results of the research shown in the graph, we can confirm that compressive strength increases with the incorporation of a certain percentage of demolition

waste.

Figure 5 presents the absorption percentage of solid bricks. The lowest value was achieved by incorporating a 15% dosage of demolition waste, achieving a value of 8.10%. Likewise, the 5% dosage of demolition waste presented the second lowest value, at 8.4%. Therefore, these dosages are the most notable among those used in this study. Among the authors who reported differing results are Patricia et al. [17], who used a 3.8% dosage of demolition waste and obtained an absorption value of 30%, considerably higher than that found in this research. Similarly, Mandefrot et al. [18] incorporated 35% waste and reported a median absorption of 19.00%. In contrast, Jhuston [19] added an even higher percentage of 40% waste but obtained a much lower absorption of 7.42%, comparable to the results of this study. With the research results shown in the graph, we can confirm that absorption increases with the addition of percentages of demolition waste, indicating a clear trend in the behavior of the material with different proportions of incorporated waste.

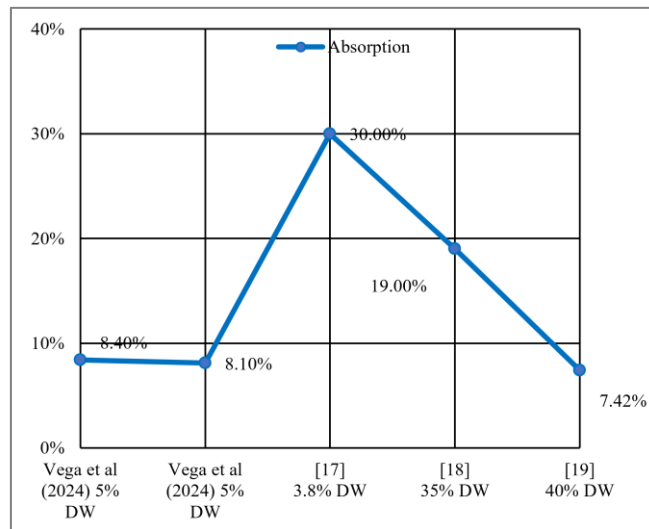


Figure 5. Absorption of solid concrete bricks according to different authors

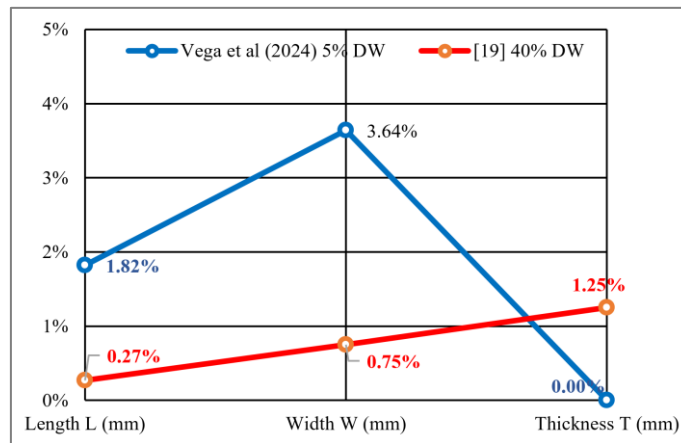


Figure 6. Dimensional variation of solid concrete bricks according to different authors

Figure 6 presents the dimensional variation of solid bricks. The lowest value resulted from incorporating a 5% demolition waste dosage, obtaining only a 1.82% variation in length, 3.64% in width, and no variation in thickness (0%), making this dosage the most notable among those implemented in this study. A complete and analogous comparison can be made with the study conducted by Jhuston [19], who, by adding 40% waste, obtained variations of 0.27% for length, 0.75% for width, and 1.25% for thickness. With the results of the research shown in the graph, we can confirm that the dimensional variation increases with the addition of demolition waste percentages; however, it remains within the required tolerance.

## 5. Conclusions

The 5% RD dosage proved to be the most suitable, as it allowed the production of bricks with a compressive strength of 23.7 MPa, exceeding the minimum standard of 21 MPa, thereby ensuring the structural safety required for construction use. This finding demonstrates that demolition waste can be incorporated into the mix without compromising the load-bearing capacity of the bricks, and even slightly improving their mechanical performance compared to the conventional mix without RD.

Regarding water absorption, a slight increase was observed as the proportion of RD increased; however, the 5% dosage showed a value of 8.13%, just above the allowed limit of 8%, indicating that the mixture maintains controlled absorption. This implies that RD bricks can adequately resist water action without compromising durability, and achieving an optimal balance between material recycling and the functional performance.

In terms of dimensional variation, bricks with 5% RD remained within the permitted tolerances ( $\pm 3.2$  mm) for manufacturing dimensions, with minimal variations in length, width, and thickness. This result shows that, although the incorporation of waste slightly increases dimensional variation, bricks that are properly controlled during production can meet quality standards, ensuring their functionality and ease of assembly in construction.

Chemical analysis of RD revealed 36.839% calcium, 29.509% silicon, 14.126% aluminum, and 10.202% iron-elements also present in sand and cement, confirming the compatibility of these wastes with conventional materials. This compatibility explains the stability of the bricks' mechanical and physical properties and reinforces the feasibility of their incorporation without risk of adverse reactions.

From a practical and sustainable perspective, the results of this study show that the use of RD in brick manufacturing contributes to reducing the environmental impact of construction by decreasing the volume of waste sent to landfills and promoting a circular economy in the construction industry. Implementing this practice not only helps conserve natural resources such as sand and cement

but also creates opportunities to develop more sustainable and environmentally responsible construction processes.

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