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Aviña Rivera Xochitl[1], Ortega Castillo Diana Alejandra[2], Herrera Ríos Erika Berenice[3], Woocay Prieto Arturo[4], Rodríguez Mejía Jeovany Rafael[5]

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[1]Master's Degree, Tecnológico Nacional de México/Instituto Tecnológico de Ciudad Juárez, Department of Metal Mechanics. xochitl.ar@cdjuarez.tecnm.mx, 6562344025, CP.32340; https://orcid.org/0009-0009-4668-7155
[2]Master's Degree, Tecnológico Nacional de México/Instituto Tecnológico de Ciudad Juárez, Department of Metal Mechanics. diana.oc@cdjuarez.tecnm.mx, 6567083897, CP.32340; https://orcid.org/0009-0001-8984-5143
[3]PhD, Tecnológico Nacional de México/Instituto Tecnológico de Ciudad Juárez, Department of Industrial Engineering. ericka.hr@cdjuarez.tecnm.mx, 6563010684, CP.32500; https://orcid.org/0000-0002-6964-5830
[4]Ph.D., Tecnológico Nacional de México/Instituto Tecnológico de Ciudad Juárez, Department of Metal Mechanics. arturo.wp@cdjuarez.tecnm.mx, 6562027409, CP. 32500; https://orcid.org/0000-0001-9235-0494
[5]Ph.D., Tecnológico Nacional de México/Instituto Tecnológico de Ciudad Juárez, Department of Metal Mechanics. rafael.rm@cdjuarez.tecnm.mx, 6567058925, CP. 32500; https://orcid.org/0000-0003-4154-0778

Abstract -- This research focuses on the search for the optimal mixture of materials to manufacture thermal bricks, considering among the main materials some that are present in the locality and that provide characteristics to the brick. Through experimentation, this research showed that the materials that were found for the mixture and manufacture of thermal bricks are: Sand, Kaolin, Lime, Gypsum, Water, Cement, Titanium oxide, Iron oxide, Diatomite, Carboxymethylcellulose (CMC). The results of tests carried out on the brick samples showed that a mixture with a high content of alfalfa as a local material, together with the materials, provided a uniform and consistent mixture and thermal properties. The bricks will be evaluated with compression test, thermal resistivity, absorption, hardness test and efflorescence test. The bricks obtained are expected to have high compressive strength, low conductivity. In conclusion, the mixture obtained from these materials allows the manufacture of high quality thermal bricks, which reduce and benefit the construction industry. The cost reduction per brick was not achieved in a conclusive way, taking care not to compromise the essential properties, providing benefits in the construction of housing in areas with extreme climates, in terms of thermal insulation and structural safety, crucial aspects to improve the quality of life in vulnerable areas of Ciudad Juarez.

Keywords: Experimentation, Thermal, Kaolin, carboxymethyl cellulose (CMC), Optimal Mixing.

Abstract -- The present research focuses on finding the optimal material mix to manufacture thermal bricks, considering local materials that would enhance the brick's properties. Through the Design of Experiments, the research identified the following materials for the mix: sand, kaolin, lime, gypsum, water, cement, titanium oxide, iron oxide, diatomite, and carboxymethyl cellulose (CMC). The results showed that a mix with a high content of alfalfa as a local material, along with the aforementioned materials, provided a uniform and consistent mix with the best properties. A press was designed and built for brick manufacturing, and the bricks will be evaluated through compression tests, thermal resistivity, absorption, hardness, and efflorescence tests. It is expected that the obtained bricks will exhibit high compressive strength and low thermal conductivity. The conclusion was that the optimal mix of these materials allows the production of high-quality, low-cost thermal bricks, beneficial for the construction industry. However, a significant cost reduction per brick was not achieved without compromising essential properties.

Key words - Experiments, Thermal, Kaolin, carboxymethyl cellulose (CMC), Optimal mixture.

INTRODUCTION

The objective of this research is that, through experimentation, to find the optimal mix of materials that include some that are found locally, for the manufacture of thermal bricks that allow homes in vulnerable areas of Ciudad Juarez, maintain a comfortable temperature and ease of access to the product.

The proposed Hypothesis is that "there is a positive relationship between the optimal mix for thermal brick manufacturing and thermal resistivity of thermal bricks".

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Thermal bricks are made of ceramic materials designed to resist high temperatures, thermal shocks and aggressive chemical environments.
For the construction of the bricks, materials were used, including silica sand, titanium oxide, iron oxide, CMC, among others. The best combinations were combined with materials that are easily found in the locality and that could help thermal brick improve its thermal resistivity and resistance properties: straw, sawdust and alfalfa. Of these, alfalfa was selected because it was the material that provided the most consistency and resistance to the touch of the sample bricks.

BUILDING MATERIALS

Sand: In [1], it is mentioned that it resists wear and weathering, its hardness in Mohs scale is 7. It is resistant to acids and water action. The compressive strength is 1600 MPa. The melting point is 1710°C. Its density is in the order of 2.65 gr/cm^3. In summary, sand in ceramic bricks controls plasticity, reduces shrinkage, improves mechanical strength, controls porosity, and contributes to the dimensional stability and surface texture of the final product. In addition, it helps to reduce costs and improve the efficiency of the manufacturing process.
Kaolin: Kaolin is a hydrated aluminum silicate, product of the decomposition of mainly feldspathic rocks, according to [2]. The term kaolin refers to clays in which the mineral kaolinite predominates. To recapitulate, it improves the quality of the ceramic brick in terms of strength, stability, and appearance.
Lime: In [3], it is stated that lime, better known as calcium oxide, is a natural chemical derived from limestone and has been used in construction since ancient times due to its unique properties. Lime is mixed with sand and water to form mortar, which is used to bind bricks, stones and other building materials. One of the most important properties of lime mortar is that it hardens to the hardness and strength of the original stone. Lime in ceramic bricks improves plasticity, accelerates drying, reduces shrinkage, controls porosity, increases water resistance and mechanical strength, and contributes to thermal stability and efflorescence control.
Gypsum: Gypsum (calcium sulfate dihydrate, $CaSO_4$-$2H_2O$) is used in the manufacture of ceramic bricks mainly as an additive. Although not major component, gypsum contributes several important properties to the manufacturing process and the final product, regulates setting time, reduces shrinkage, improves workability, controls porosity, and contributes to dimensional stability and a smoother brick surface
Cement: In [4] it is mentioned that it is a fundamental material in the construction of bricks because of its properties that improve the quality, durability and strength of structures, it contributes to the compressive of mortar or concrete used in brick construction. It ensures that structures can withstand significant loads without deforming or collapsing, it can help make brick constructions more waterproof, protecting them from water penetration and preventing structural damage from moisture, and it is easy to work with.
Diatomite: According to [5], diatomite earth is a siliceous sedimentary rock of biological origin formed from the fossil skeleton of diatomite shells. When added to the clay mixture to make ceramic bricks, diatomite provides several beneficial properties, provides lightness, improves thermal and acoustic insulation, and increases fire resistance in ceramic bricks. However, it is important to balance its quantity to avoid excessive porosity that could affect mechanical strength.
Iron oxide (hematite): [6], mentions that iron oxide red III, Fe2O3, (known as hematite) is a naturally occurring iron mineral that has a wide range of uses beyond simply being a source of iron. Apart from improving aesthetics, this material can increase the weather resistance of bricks, making them more durable against prolonged exposure to natural elements such as rain, wind and temperature variations, it can also influence the plasticity of the mix, improving workability and facilitating the molding of the bricks.
Titanium oxide: [7] specifies that rutile is a group IV mineral (according to the Strunz classification) whose chemical composition is titanium oxide.
(IV) (TiO2). In ceramic bricks, it improves whiteness, opacity, and resistance to chemical and UV agents, in addition to offering photocatalytic properties and improving the thermal and dimensional stability of the final product.

CMC: Carboxymethylcellulose (CMC) is a versatile polymer widely used in the construction industry, particularly in the formulation of dry mortar. It is mentioned in the results of [8], that the unconfined compressive strength (UCS) increased by 76.7% with 0.5% of NaCMC treated soil after 28 days. The use of CMC in ceramic bricks improves plasticity, controls water , reduces shrinkage and cracks, increases the green strength, improves the homogeneity of the mixture and surface quality, and reduces dust during the manufacturing process; it should be properly dosed, since in excessive amounts it can generate problems such as excessive water retention, which could hinder the final drying of the bricks.

DEVELOPMENT

Sample mix design.

Prior to this, the review of the bibliography showed some materials that are used in the manufacture of bricks, in this case, six mix factors were used with 3 repetitions, the upper and lower limits were defined, which are shown in Table 1. In this mix design, the sum of the proportions must be unity, even when they have restrictions or are in pure form.

During the experimentation, out of the ten mixtures, #4 and #8 were selected; which presented sample bricks whose preparation mixtures had a complete adhesion consistency of the materials, a fast drying and a hard consistency to the touch upon drying. Straw, sawdust and alfalfa were added to these mixtures because they are materials with the following characteristics:

1. Fibrous Structure: Alfalfa is composed of natural fibers that create a network capable of trapping air. Air has a low thermal conductivity, which increases the thermal resistivity of the material.
2. Low Density: Materials with alfalfa usually have a low density, which reduces thermal conductivity, since the less dense material is less able to conduct heat.
3. Interaction with Other Materials: When alfalfa is mixed with other components, such as lime, cement or clay, it can improve the thermal resistance of the resulting material. These biocomposites can offer a sustainable solution for improving insulation in buildings. Alfalfa was chosen from these three materials. The experimentation, the optimal mix for sample size bricks, the selected mix with the local material and the results of the compression and thermal resistivity tests are presented below.

Table 1. Upper and lower limits of experimentation.

Material	Inf. Inf.	Lim. Sup.	Experiment #4	Experiment # 8
Silica sand	25	35	25	26
Kaolin	20	25	15	17
Cal	10	20	10	15
Gypsum	8	18	10	5
Water	10	20	18	17
Cement	3	13	5	3
Alfalfa			10	10

The percentages used to manufacture the bricks are shown in Table 2.

Brick manufacturing.

The work was carried out in 5 mixtures as shown:

1. MIXTURE 1: The proportions were defined for the mixture of experiment # 4, according to the amount of sand to be used, the alfalfa was reduced, because when compacting the bricks, this was not achieved. We took 1.95 kg of mixture to place it in the press and with 1 ton of pressure we obtained a compacted brick with an approximate weight of 1.925 kg, which can be seen in the figure below.

1. With a drying time of 24 hours, the brick finished with an average weight of 1.26 kg. The final consistency of the bricks, in general, was that 67 % were firm, 19 % were firm and 19 % were firm.

% fractured and with pores and 14% with pores.

Figure 1. Compacted brick, Mix 1.

Of this mixture, 21 bricks were obtained, of hard and completely dry consistency, as shown in Figure 2, bricks of the first row.

Figure 2. Bricks of Mix 1 and Mix 3.

2. MIXTURE 2: This mixture was developed with 21.75 kg of sand, when mixing it a lack of consistency was observed, so 1 more kg of cement was added for a total of 4.35 kg, this achieved a uniform mixture that was easy to work with. 1.95 kg of the mixture was taken to place in the press and with one ton of pressure a uniform brick of 1.922 kg average was achieved. After 24 hours of drying, the brick has 1.20 kg. 27 bricks with 24 hours of drying are shown in Figure 3. The final consistency of the bricks was 48% were firm, 41% with few lesions, but firm, 11% with voids, but firm.

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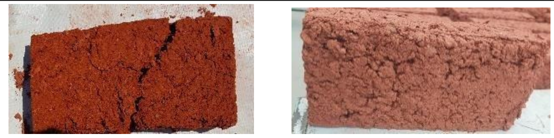
Figure 3. Dry bricks, Mix 2.

3. MIXTURE 3: This mixture was developed with 21 kg of sand and the corresponding proportion, at the beginning of the mixture large lumps of material were formed, which were removed with the hands.
   40 minutes of mixing resulted in a uniform mixture with some lumps, but easy to work with. 1.95 kg of the mixture was taken to place in the press and with one ton of pressure a uniform brick of 1.92 kg average was achieved. After 24 hours of drying, the brick has 1.09 kg. The 30 bricks made with this mix are shown in Figure 1 in rows 2 and 3. The final consistency of the bricks, in general, was that 53% were firm, 30% with pores and 17% with some small cracks or lesions.

4. MIXTURE 4: This mixture was developed with what was considered in Experiment # 8. It was developed for 22 kg of sand and with the proportions that this one marked. The mixture became very complicated, since it formed balls of material that were very difficult to break up, as shown in Figure 4. It was stirred for approximately one hour and 5 kg more water was added than the proportion indicated; at the end of that time it was consistent enough for modeling. 1.95 kg were used to make the brick, after compaction it was 1.90 kg, with 24 hours of drying the brick finished with 1.20 kg. Figure 5 shows these bricks, (a) wet and (b) dry.
   (b) with 24 hours of drying, as can be observed, the consistency of these bricks is lumpy. Of these bricks, 14% were very lumpy but compact, 8% lumpy but incomplete, 31% with lesions on the sides, 42% with pores and 5% with fractures.

Figure 4. Mix 3 inside the mixer.



(a) *(b)*

Figure 5. Mixing Bricks 4.

5. MIX 5: This mix was developed with 21 kg of sand and the corresponding proportion according to the mix design. In the previous mixes it was observed that the CMC was the one that made the mixture form balls, so when analyzing the properties it contributed to the brick: water retention to prevent cracking, improve the final surface, dust reduction, i.e., only surface quality properties, it was decided to eliminate it. The mixture was uniform, easy to handle, no balls of material were formed and the mixing was for 20 minutes, it is worth mentioning that the kaolin and gypsum adhered at the end, since they are materials that absorb a lot of water. Thirty-nine bricks were made. It is observed in the figure 1.95 kg of mixture was used to form the brick, compacted 1.91 kg and 1.44 kg with 24 hours of drying. In Figure 6, a brick with 24 hours of drying is observed. Seventy percent of the bricks had a very firm final consistency and the remaining 30 % had some pores, but remained firm.

Figure 6. Dry brick, Mix 5.

Table 2 Percentage of material per mix.

Material	M1	M 2	M 3	M 4	M 5
Sand	25.00	25.00	25.00	24.07	26.80
Kaolin	15.00	15.00	15.00	13.34	16.03
Cal	10.00	10.00	10.00	11.77	10.72
Gypsum	10.00	10.00	10.00	5.76	10.72
Water	17.99	17.99	18.00	27.52	25.52
Cement	5.00	5.00	5.00	4.19	5.36
Alfalfa	10.0	10.0	10.00	7.84	1.44
Titanium oxide	1.00	1.00	1.00	0.79	1.07
Iron oxide	2.50	2.51	2.50	1.96	1.28
Diatomite	1.00	1.00	1.00	0.79	1.07
CMC	2.50	2.51	2.50	1.96	0
Total	100.00	100.00	100.00	100.00	100.00

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Brick test

Three essential tests will be carried out to evaluate the manufactured bricks and compare them with conventional bricks.

Absorption Test

ASTM C67 [9] is a standard reference used for the sampling and testing of clay structural bricks and tiles. This standard includes tests for various properties, including water absorption.

ISO 10545-12:1995 [10] establishes the method for determining the water absorption of ceramic products. Although the standard specifies the procedure for performing the test, it does not define specific water absorption values to be achieved. These values vary depending on the type of ceramic product and its application.

Water Absorption Test Procedure:

1. Sample Preparation:

o The samples are dried in an oven at a temperature of 105°C to 110°C until a constant weight is reached.

2. Water Immersion:

o The dried samples are immersed in water at room temperature for a period of 24 hours.

3. Weight Measurement:

o The weight of the samples is measured before and after immersion in water.

4. Water Absorption Calculation:

$$Absorción = \frac{WH - WS}{WS} * 100 \qquad \text{Eq. (1)}$$

Where

WH Wet weight of sample WH Dry weight of sample

Efflorescence is evaluated with the same test. [12] refers to the formation of whitish deposits on the surface of building materials such as bricks, concrete, or stone. This phenomenon occurs when soluble salts present in the building materials or in water percolating through them dissolve in the water, and then, as the water evaporates on the surface, the salts are deposited. Although efflorescence does not usually affect the structural integrity of the material, it can be an aesthetic concern, as it alters the appearance of the affected surface. In addition, its presence may indicate moisture problems, which could have long-term implications for the durability of the structure.

The standard [10], entitled "Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile", includes a method for evaluating efflorescence in structural clay bricks. According to this standard, efflorescence is classified into four categories based on visual observation of the bricks after a water immersion and drying process:

a) None: No efflorescence is observed on the surface of the brick.
b) Slight: A small amount efflorescence is observed on less than 10% of the surface of the brick.
c) Moderate: Efflorescence covers between 10% and 50% of the surface of the brick.
d) Heavy: Efflorescence covers more than 50% of the surface of the brick.
e) Excessive: Efflorescence covers almost the entire surface of the brick and may be associated with visible damage to the material, such as flaking or surface disintegration.

Four bricks were taken from each mixture and immersed for 24 hours in normal water, placed in containers so that they were completely submerged, ensuring that the water level remained constant throughout the test period. The results are shown in Table 3.

Table 3. Absorption test results.

Mezcla	Sample No.	% Absorption	ISO Standard Classification 10545-3	ASTM Standard Classification C67	Efflorescence
1	18	33.57	G BIII	High	None
1	19	33.58	G BIII	High	None
1	6	33.87	G BIII	High	None
1	7	34.37	G BIII	High	None
2	9	47.10	G BIII	High	Slight
2	8	50.42	G BIII	High	Slight
2	19	48.76	G BIII	High	Moderate
2	20	51.66	G BIII	High	Slight
3	19	54.12	G BIII	High	Moderate
3	11	54.86	G BIII	High	Heavy
3	10	55.26	G BIII	High	Heavy
3	24	55.75	G BIII	High	Heavy
4	8	46.28	G BIII	High	Heavy
4	35	48.33	G BIII	High	Heavy
4	7	48.76	G BIII	High	Heavy
4	36	48.76	G BIII	High	Heavy
5	12	26.89	G BIII	High	None
5	13	26.89	G BIII	High	None
5	34	29.16	G BIII	High	Slight
5	35	29.37	G BIII	High	Slight

Compression Test

In [12] discusses the compression test on building materials, including bricks, and mentions that this test is a fundamental property measured to evaluate the quality of building materials. The purpose of this test is to determine the ability manufactured bricks to withstand loads before failure, as this measure is crucial of the structural strength of the material.

As well as [12] addresses topics such as the physical and mechanical properties of concrete, the behavior of the

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material under different conditions, and testing and quality control techniques.

The standard [10]: Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile, specifically details the method for testing the compressive strength of structural clay brick and tile. Following the test method proposed by the standard, the following is a description of what has been done:

a) Sample Selection and Preparation:

Representative bricks were randomly selected for testing. The samples were dry and free of visible defects. Most of the selected samples were flat, so they were not ground.
Clarifying that these bricks were not kiln-dried but dried at room temperature.

b) Test Equipment: The Galdabini Universal Machine was used, calibrated and equipped with a program which is capable of accurately measuring the load.

c) Testing Process: The specimen is placed in the compression machine so that the load is applied perpendicular to the faces that will support the load in its final use. It is shown in Figure 7.

d) Compressive Strength Calculation: The compressive strength was calculated by dividing the maximum applied load (in Newtons) by the area of the loading surface (in square millimeters).
The equation used is:

$$\sigma = \frac{F}{A} \qquad \text{Eq. (2)}$$

Where

σ is the Compressive Strength in MPa F is the Maximum Load Nw
A is the Area of the surface mm^2

Figure 7. Sample brick of Mix 4 in Universal Machine.

The compression test results are shown in Table 4.

Table 4. Compressive strength test results.

MIX	AVERAGE Compressive Strength Tons	AVERAGE Ultimate Strength Tons

1	6.149	0.000
2	2.928	2.919
3	2.246	2.244
4	2.448	2.446
5	10.478	2.447

Temperature Transmission Test. The standard [13]: Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus describes a method for measuring the thermal conductivity and thermal resistance of materials using a heat flow meter apparatus.

The method described in the standard is detailed below:

<u>Principle of the Method</u>: The method is based on the measurement of the heat flow through a sample of the material in a stationary state, when a temperature difference is applied between the two opposite surfaces of the sample. This test lasted 4 hours, during which time the temperature inside the chamber was kept stable; measurements were recorded every 5 minutes during the first hour of the test and then every 10 minutes during the remaining 3 hours of the test. The heat flow meter apparatus measures the resulting heat flow, which is used to calculate the thermal conductivity of the material.
Heat flux sensors: This was positioned to measure the heat flux passing through the sample.
Thermocouples or resistance thermometers: They are used to measure the temperature of sample surfaces.
<u>Sample Preparation</u>: The sample was built with 10 bricks of each mix, achieving a wall of 48 cm wide by 33 cm high, the wall thickness 11 cm. A sample of it is shown in Figure 8.

Test for Calculation of Thermal Conductivity k: Thermal conductivity is calculated using the following Equation:

$$k = \frac{q * \Delta x}{A * \Delta T} \qquad \text{Eq. (3)}$$

Where

k en Thermal conductivity in
q is the heat flux density (W/m²) A is the Area of the surface m^2
Δx is the thickness of the sample (m),
ΔT is the temperature difference between the two surfaces (K

Results:
The thermal conductivity, which is a measure of the material's ability to conduct heat, is obtained.
Thermal resistivity, which is the inverse of thermal conductivity, can also be obtained.
Calibration: It is crucial to properly calibrate the heat flow meter prior to taking measurements to ensure accurate results.

Test Conditions: Environmental conditions, such as temperature and humidity, should be carefully controlled to avoid interference with the measurements.
The measurements were performed on walls formed by 10 bricks of each mixture, resulting in an arrangement as shown in Figure 8.

Figure 8. Arrangement for temperature difference measurement.

In reality, the data of interest is the thermal resistivity, which is the inverse of the conductivity,
The results of the test are presented in Table 5.

Table 5. Heat flux test results.

MIX	Conductivity Thermal k W/(m.ºK)	Resistivity Thermal C (m.ºK)/W
1	0.95	1.05
2	1.13	0.88
3	1.13	0.88
4	1.15	0.87
5	1.49	0.67

Price per brick
The price of bricks made from materials purchased in Ciudad Juárez varies considerably depending on the quality of the inputs used and their availability in the local market. These materials, which include clay, cement, sand and special additives, directly influence the final cost of the product, which is reflected in the pricing options available to consumers. The materials used were purchased from local stores and some were purchased at retail, which could increase their cost. The cost per brick per mix is presented in Table 6.

Cost per brick.

MIX	Cost pesos
1	$ 125.66
2	$ 146.77
3	$ 127.40
4	$ 67.47
5	$ 66.42

DISCUSSION AND ANALYSIS OF RESULTS

In [5] it was identified that handmade bricks have been studied with the purpose of adding organic compounds to improve their mechanical properties. As is the case where up to 40% of the sand in its manufacture is replaced by diatomite residues obtained from a brewery plant in order to determine whether they meet the requirements stipulated in [15]. In contrast, in the present investigation we worked with the absorption test that allows us to conclude that according to the ASTM C67 Standard, all the pieces exceed 20% of permissible or acceptable absorption for construction bricks, in conditions where exposure to humidity is a critical factor, which is not the case in Ciudad Juarez, since the climate is dry both in summer and winter. Therefore, the 28% that the pieces of Mixture 5 brick have would be optimal for use in construction. In contrast, as mentioned in [3], where the development of eco-friendly bricks with a matrix of recycled materials from 3% to 10% is framed, achieving strengths of up to 175 kg/cm^2.

In [16], a study is described that compares the thermal properties of bricks made from construction and demolition waste with clay and cement , focusing on thermal insulation and conductivity, while evaluating environmental performance and sustainability principles through recycling in architecture. Bricks made from construction waste and rubber show the highest thermal insulation.
Bricks demonstrate better mechanical properties than traditional options. The study highlights the potential of recycled materials in construction applications.
The pieces manufactured in this investigation that were subjected to the compression test and the results of this test are shown in Table 3. In the observations of the tests, the following can be observed in each of the groups of bricks per mix:

Mixture 1: 40% of the bricks crumbled as shown in Figure 9 and the remaining 60% came out whole, but with fractures or broken edges. Since it is a very fragile mix, the Ultimate Strength data was not recorded in Universal Machine.

Mix 2: 70% of the bricks ended up broken, 10% came out complete, but when removed from the Machine it crumbled and the remaining 20% ended up complete.

Mixture 3: 60% of the bricks came out complete with some fractures, the remaining percentage crumbled in the test.

Mixture 4: 50% of the bricks are complete with fractures and brittle, the remaining percentage is complete.

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after testing, but fell apart when removed from the universal machine.
Mixture 5: 70% of the bricks come out complete, 20% of the bricks come out complete with visible fractures, but do not break and 10% were shattered during loading. As shown in Figure 10

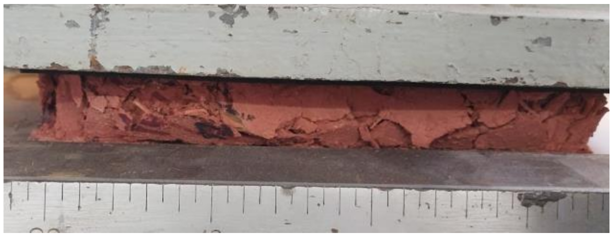

Figure 9. Mix 1 brick, crumbled after compression test.

Figure 9. Mix 1 brick, crumbled after compression test.

According to the distribution of the mixtures, in [7], the effect of the addition of iron oxide scrap was investigated in which the mechanical and microstructural properties of bricks are improved according to the addition of 10 % and 15 % of iron oxide for the manufacture of bricks. In this research, the bricks of mix 5 were able to maintain their shape even with 10 tons in the compression test. This improvement in mechanical strength could be related to the synergy between the composition of the mixture and the stabilizing effect of iron oxide, which reaffirms the trend observed in previous studies, such as that of [7], in which it was shown that the incorporation of this oxide not only improves the structural properties, but also contributes to greater stability of the material under loading conditions.

If we compare the thermal resistivity of CDW bricks, they usually have a **thermal resistivity** between **0.20 and 0.20. 0.35 m-K/W** [16], with that of that obtained with the bricks of mix 4, it can be observed that: Thermal resistivity measures the ability of a material to resist heat flow: the higher the resistivity, the better the material is a thermal insulator, since it allows heat to be transferred with greater difficulty. In this case:

- **0.67 m-K/W** indicates a material with **higher resistance** to heat flow. Data from Table No. 5
- **0.2 m-K/W** indicates a material with lower resistance to heat flow.

CONCLUSIONS

From the absorption test it can be concluded that the bricks of mix 5 had an average absorption rate of 28% compared to the other mixes that had up to a little less than 55%; addition, the bricks of mix 5 had no or slight efflorescence.
From the compression test it is concluded that the brick of mix 5 manages to maintain its shape even after having withstood a compression load of more than 10 tons; compared to the other mixes that did not withstand more than 3 tons in their majority.
From the temperature transmission testit can be seen that, contrary to what was expected, the bricks of mix 5 were better heat conductors than the other mixes. As shown in Table 5, the bricks of this mix, with low resistivity, indicate that the material would allow a higher heat flow, being a more efficient heat conductor. Summarizing, the tests of this mixture after 4 hours with a temperature of 85.1ºC inside the chamber, had passed 45.2 ºC, which is almost half.
[14] mentions in his book that the coefficient of resistivity of conventional bricks is approximately 0.67 m-K/W and of thermal (insulating) bricks approximately 2.0 - 4.0 m-K/W. Therefore, considering these data and contrasting them with the thermal resistivity obtained experimentally from the five proposed mixtures, it can be concluded that any mixture can be efficient to maintain a comfortable temperature inside the homes of Ciudad Juarez.
Considering that the average price of a conventional commercial thermal brick is $120 and comparing it with the calculated prices of the proposed mixes, it can be concluded that any of the mixes offers a competitively priced brick.
In general, it can be concluded that, according to the results obtained from the tests of the properties evaluated, mix 5 is the most efficient in all aspects considered in this research and is good for the construction of one-story houses in Ciudad Juárez.
In future works, it is planned to build a wall with the material of mix 5, which is the one considered optimal to carry out the tests of. Compression, efflorescence and calculation of thermal conductivity. The objective of these tests is to evaluate the structural strength and durability of the wall, as well as its behavior against environmental factors, thus ensuring that it meets the quality standards required for its application in construction and improving its thermal efficiency to optimize energy consumption in buildings.

It is also planned to investigate the dehydration process, it is to perform a dehydration process of the mixture, in such a way that the powder can be had and sold so that only water is added in the proportions indicated. The objective of this approach is to simplify the process of preparing the material for the users, facilitating its handling and storage. In addition, it seeks to offer a product that is more accessible and convenient for builders, thus optimizing time and resources in their projects.

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BIBLIOGRAPHY .

[1] Cahuaya Choque, J. C. (2022). Raw Clay-Silica Bricks and the Improvement of Mechanical Properties of Masonry in the District of Huancayo. Repositorio de la Universidad Peruana Los Andes. https://hdl.handle.net/20.500.12848/3808

[2] Baca, J. C., & Galvez, L. G. (2021). Behavior of handmade clay bricks in their axial compressive strength between masonry units and piles made with kaolin clay from the city of Huamachuco and units and piles from the city of Jaén, Trujillo 2021 [Tesis de licenciatura, Universidad Privada del Norte]. Repository of the Universidad Privada del Norte. https://hdl.handle.net/11537/30798

[3] Benavidez-Rubio, D. Y., & Benavidez-Núñez, C. E. (2021). Characterization of concrete brick with hydrated lime and recycled PET plastic: Characterization of concrete brick with hydrated lime and recycled PET plastic. Revista Ciencia Norndina, 4(2), 34-46.

[4] Neville, A. M., & Brooks, J. J. (2010). Concrete technology (2nd ed.). Pearson.

[5] Guevara Dávila, R. (2022). Evaluation of artisanal brick partially substituting sand for diatomite waste, Motupe. https://hdl.handle.net/20.500.14142/261

[6] Bautista Marín Jesús David (2020). Manufacture and characterization of Eco -friendly bricks with the addition of an industrial iron residue. Colombian School of Engineering Julio Garavito. https://repositorio.escuelaing.edu.co/handle/001/1212

[7] Gelves-Díaz, J. F., Sánchez-Zuñiga, J. V., & Sánchez-Molina, J. (2021). Physicochemical characteristics of refractory bricks used in kilns of the ceramic industry in eastern Colombia. Mundo FESC, 11(S2), 250-261.

[8] Evangelin, Ramani, Sujatha, Govindan, Kannan (2022). An Investigation on the Potential of Cellulose for Soil Stabilization. Sustainability, doi: 10.3390/su142316277

[9] ASTM International Standard (2017). ASTM C67-17: Standard test methods for sampling and testing brick and structural clay tile. ASTM International. https://doi.org/10.1520/C0067-17

[10] Standard International Organization for Standardization (1995). ISO 10545-12:1995 Ceramic tiles - Part 12: Determination of frost resistance. ISO.

[11] Mamlouk, MS, and Zaniewski, JP (2006). Materials for civil and construction engineers (pp. 8-10). Upper Saddle River, NJ, USA: Pearson Prentice Hall.

[12] Neville, AM (1995). Properties of concrete (Vol. 4, p. 1995). London: Longman.

[13] ASTM Standard C518-17: Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus

[15] Ministry of Housing, Construction and Sanitation (MVCS) (2020). *Technical standard E.070: Masonry*. Retrieved from https://www.gob.pe/norma_tecnica_e070

[16] Hesham, Hassan, Eman, Mohamed. (2023). Experimental Study to Compare Thermal Properties of Bricks Made from Construction and Demolition Waste with Clay and Cement bricks. Deleted Journal, 4(1):84-98. doi: 10.21608/njace.2024.341292.

CONTRIBUTION ROLES

Role	Author(s)
Conceptualization	Xóchitl Aviña Rivera
Data Curation	Erika Berenice Herrera Ríos (Principal) Arturo Woocay Prieto (Supporter)
Methodology	Diana Alejandra Ortega Castillo (Principal) Xochitl Aviña Rivera (Supporter)
Administration Pr oject Management	Xochitl Aviña Rivera
Resources	Jeovany Rafael Rodríguez Mejía
Software	Diana Alejandra Ortega Castillo (Principal) Jeovany Rafael Rodríguez Mejía (Supporter)
Supervision	Xochitl Aviña Rivera
Validation	Erika Berenice Herrera Ríos
Visualization	Xochitl Aviña Rivera
Editorial staff	Diana Alejandra Ortega Castillo
Editorial staff	Xochitl Aviña Rivera (Principal) Diana Alejandra Ortega Castillo (Supporter)

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