Concrete bricks with recycled rubber fibers: an alternative material for social housing

Ladrillos de concreto con fibras de caucho reciclado: un material alternativo para viviendas de tipo social

Tijolos de betão com fibras de borracha recicladas: um material alternativo para moradias de tipo social

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Abstract

Introduction: This research article “concrete brick with the addition of recycled rubber” was carried out in 2019 at the Faculty of Civil Engineering of the UNSA.

Problem: The need to close the gap in the housing sector, especially for people with low economic resources and contribute to the reduction of atmospheric pollution due to the burning of tires in the manufacture of artisan bricks in the city of Arequipa.

Objective: To find a more economical masonry unit with the same resistance as mechanized bricks, which can be manufactured and used by the inhabitants of the poorest segments of the city, using the rubber from used tires.

Methodology: For the research we induce the object of study, through different additions of rubber in the mixture, this experimentation allows us to find through different tests, the physical and mechanical properties of the LCR, describing the results of the tests carried out on the LCR masonry units and KKH10.

Originality: In the bibliographic review the use of recycled rubber is found in concrete, we propose to find a brick made with a mixture of concrete and recycled tire rubber fibers to replace the fine aggregate that we will call “Bricks with Recycled Rubber” (LCR), our purpose is that it achieves the same characteristics of a type IV unit and meets the minimum requirements established by Standard E.070

Limitations: It has not been had since the materials used are of universal use, although it could be the quality of cement.

Results: The LCR-I brick, which is classified as type IV, is of good quality, handcrafted, and friendly to the environment. This brick has a cost of $ 0.251 US dollars, that is, 12% cheaper than the most widely used mechanized brick in the city.

Keywords: Rubber recycled, masonry, bricks, materials testing, social housing.

Resumen

Introducción: El presente artículo de la investigación “ladrillo de concreto con adición de caucho reciclado”, se realiza en 2019 en la Facultad de Ingeniería Civil de la UNSA.

Problema: La necesidad de cerrar la brecha del sector vivienda, en especial de las personas de bajos recursos económicos y contribuir a la disminución de la contaminación atmosférica por efecto la quema neumáticos en la fabricación de ladrillos artesanales en la ciudad de Arequipa.

Objetivo: Encontrar una unidad de albañilería más económica y de la misma resistencia que los ladrillos mecanizados, que pueda ser fabricado y utilizado por los pobladores de los segmentos más pobres de la ciudad, empleando el caucho de los neumáticos usados.

Metodología: Para la investigación inducimos el objeto de estudio, mediante diferentes adiciones de caucho en la mezcla, esta experimentación nos permite encontrar mediante diferentes ensayos, las propiedades físicas y mecánicas del LCR, describiéndose los resultados de los ensayos realizados a las unidades de albañilería LCR y KKH10.

Originalidad: En la revisión bibliográfica se encuentra el uso de caucho reciclado en los concretos, nosotros proponemos encontrar un ladrillo elaborado con mezcla de concreto y fibras de caucho de neumático reciclado en reemplazo del agregado fino al que denominaremos “Ladrillos con Caucho Reciclado” (LCR), nuestro propósito es que este alcance las mismas características de una unidad del tipo IV y cumpla con los requerimientos mínimos establecidos por la Norma E.070

Limitaciones: No se ha tenido ya que los materiales empleados son de uso universal, aunque podría ser la calidad de cemento.

Resultados: El ladrillo LCR-I el cual clasifica como tipo IV siendo de buena calidad, de fabricación artesanal, amigable con el medio ambiente. Este ladrillo tiene un costo de $ 0,251 dólares americanos, es decir, 12% más económico que el ladrillo mecanizado más empleado en la ciudad.

Palabras claves: Caucho reciclado, albañilería, ladrillos, ensayo de materiales, vivienda social

Resumo

Introdução: Este artigo de pesquisa “Tijolo de concreto com adição de borracha reciclada” foi realizado em 2019 na Faculdade de Engenharia Civil da UNSA.

Problema: A necessidade de fechar a lacuna no setor habitacional, principalmente para pessoas com poucos recursos econômicos, e contribuir para a redução da poluição do ar devido à queima de pneus na fabricação de tijolos artesanais na cidade de Arequipa.

Objetivo: Encontrar uma unidade de alvenaria mais econômica e com a mesma resistência dos tijolos mecanizados, que possa ser fabricada e utilizada pelos moradores das camadas mais carentes da cidade, a partir da borracha de pneus usados.

Metodologia: Para a investigação induzimos o objecto de estudo, através de diferentes adições de borracha na mistura, esta experimentação permite-nos encontrar através de diferentes testes, as propriedades físicas e mecânicas do LCR, descrevendo os resultados dos testes efectuados no Unidades de alvenaria LCR e KKH10.

Originalidade: Na revisão bibliográfica o uso de borracha reciclada é encontrado no concreto, propomos encontrar um tijolo feito com uma mistura de concreto e fibras de borracha reciclada de pneu para substituir o agregado fino que chamaremos de “Tijolos com Borracha Reciclada” (LCR), nosso objetivo é que ele atinja as mesmas características de uma unidade tipo IV e atenda aos requisitos mínimos estabelecidos pela Norma E.070

Limitações: Não ocorreu visto que os materiais utilizados são de uso universal, embora possa ser a qualidade do cimento.

Resultados: O tijolo LCR-I, classificado como tipo IV, é de boa qualidade, feito à mão e amigo do meio ambiente. Esse tijolo tem um custo de $ 0,251 dólares americanos, ou seja, 12% mais barato que o tijolo mecanizado mais utilizado na cidade.

Palavras-chave: borracha reciclada, alvenaria, tijolos, teste de materiais, habitação social

1. INTRODUCTION

The recycle of disused rubber and other materials in construction is a necessity and of great help to reduce the environmental impact generated by these materials, as they are produced without any waste mitigation plan.

In today's world, the advances in research of innovative, ecological, economic and quality materials used in construction are growing, but the problem of waste is being aggravated in developing countries where the awareness about the issue has not yet been realized, that is why the need to resort to greener practices and that the preservation of resources is achieved through the concepts of reduction, reuse and recycling. [12].

Therefore, there is an urgent need to improve existing applications and develop new applications for recycled tires and one of the applications that is being investigated is the use of waste tire rubber as a partial replacement for conventional aggregates in concrete applications [2]. So far, a great deal of research has been done to detect the effects of rubber particles on concrete properties and most forms of recycling consisted of crushing and shredding scrap tires into various particle dimensions and using on concrete mixture.

On the other hand, there are research that focuses on the use of recycled rubber in the production of concrete, most of the studies reported were on normal strength concrete with waste tires as a replacement for natural aggregate, so there are few studies available that analyze the effect of adding recycled rubber to high-strength concrete, therefore further studies are required to evaluate the performance of high-strength concrete containing recycled rubber. The concrete made with rubber fibers makes it lighter and more ecological.

The disadvantages of conventional concrete are the cracking due to contraction and expansion, while in different investigations it was shown that rubber is suitable to improve the previous disadvantages of unit weight and reduction of cracks, which make it possible to use it in places where it is require larger non-structural concrete elements [18].

In Peru there are several retreading plants, including RELINO S.A. located in the city of Arequipa that repairs and rebuilds tires in addition to other retreading centers which is the most widespread form of tire recycling in our country, although the recycling of tires disabled by mechanical or chemical means for their incorporation into new materials of construction or others is not recognized. There is a background of its application and experimentation in different types of pavements without any application in public or private companies, that is why an ecological, sustainable and quality material is proposed.

2. MATERIALS AND METHODS

a. Experimental Program

The present investigation is of a correlational experimental type, so it was carried out in the concrete laboratory of the Faculty of Civil Engineering of the National University of San Agustín de Arequipa, to obtain the brick with recycled rubber (RRB), fibers of recycled tire rubber were added to replace fine aggregate, in order to obtain the optimum quantity according to our proposed combinations and behavior.

A study of the used materials was performed, as well as the study of the different dosages for the elaboration of the RRB bricks and the respective tests to determine and verify the physical and mechanical properties of the brick.

Pozzolanic cement IP

It was used the most commercialized cement in the city of Arequipa, this belongs to the company Yura S.A. with the Yura IP brand, which is the type of cement suitable for mortars according to studies; the physical and mechanical characteristics of Yura IP cement are shown in table 1, below.

Table I. Physical and mechanical characteristics of cement Yura type IP.

REQUIREMENTS CHEMICAL REQUIREMENTS	YURA CEMENT TYPE IP		REQUIREMENTS STANDARD NTP 334,090 ASTMC-595			
MgO (%)	15 a 24		6,00 Max			
SO3(%)	15 a 23		4,00 Max			
Loss on ignition (%)	15 a 38		5,00 Max			
PHYSICAL REQUIREMENTS						
Specific weight (gr cm3)	2,77 a 2,85					
Expansion in autoclave (%)	-0,05 a 0,03		o,20 a 0,80		**REQUIREMENTS NTP 334,009 ASTMC-150 (TYPE I CEMENT)**	
Initial Vicat Set (minutes)	170 a 270		45 a 420			
Air content	25 a 80		12 Max			
Compressive strength	**Kg.f/cm²**	**Mpa**	**Kgf/cm²**	**Mpa**	**Kgf/cm²**	**MPa**
1 day	80 a 104	78 a 102				
2 days	175 a 200	171 a 196	133min	13	122 min.	12
7 days	225 a 260	220 a 254	204 min	20	194 min.	19
28 days	306 a 350	300 a 343	255 min	25		
Sulfate resistance	**%**		**%**			
% Expansion at 6 months	<0,021%		0,05 Max			
% Expansion to 1 year	<0,023%		0,10 Max			

Source: Yura cement technical data sheet.

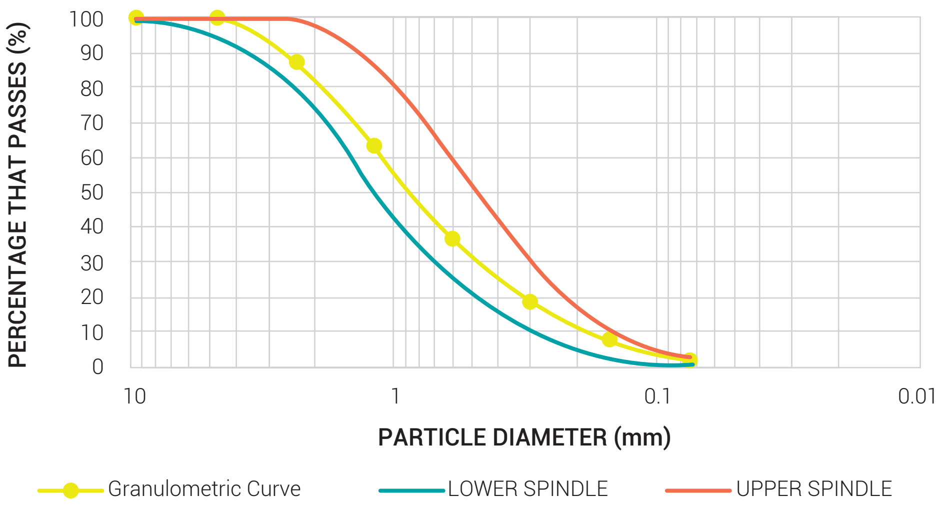
Aggregates

The Peruvian technical standards establish a large part of the tests on aggregates, so we have: NTP.400.012.2013: "Granulometric analysis of fine, coarse and global aggregate.", NTP.400.017.2011: "Method of test to determine the mass per unit volume or density (unit weight) and the voids in the aggregates ", NTP.400.022.2013:" Standard test method for the specific weight and absorption of fine aggregate "; additionally, there are the following international standards ASTM C-33: "Specifications of Aggregates for Concrete", ASTM C-75: "Sampling of Aggregates': ASTM C-128:" Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate "and ASTM C-136: '' Granulometric analysis of fine and coarse aggregate".

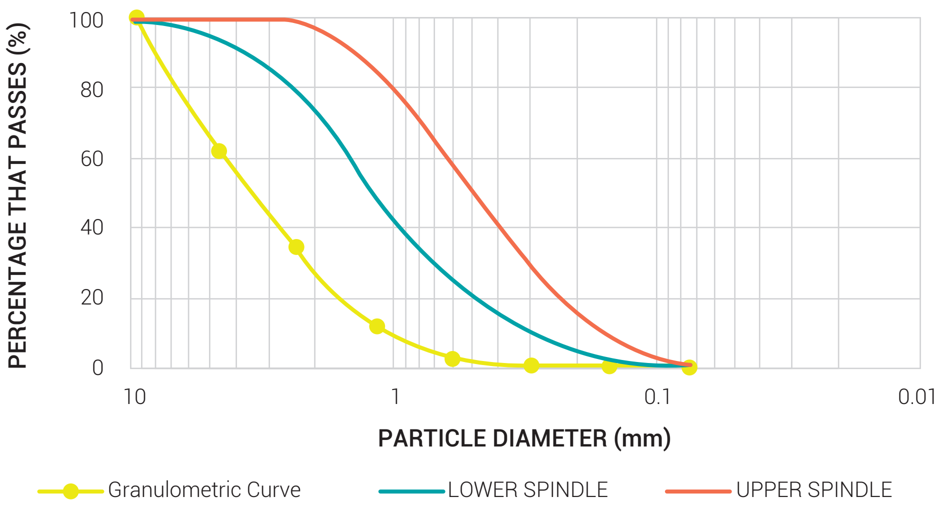
For the respective sampling, the aggregates must be clean or free of solid impurities or others that affect their properties before and after mixing, "La Poderosa" quarry was chosen since it showed good results for concrete analysis in other investigations, the sample was prepared according to NTP400.010.2011 "Aggregates: extraction and sample preparation".

The city's materials were used, knowing that there are stone aggregates produced in the city that are the most used in investigations due to their ideal characteristics for construction, such as aggregates from the SUPERMIX company, La Poderosa, and Yura IP cement., being the ones used in order to focus on the behavior of the new incorporated material. The recycled tire rubber fibers that are the aggregate to be incorporated in the study are sourced from retreading plant RELINO S.A., which was visited to learn about the process of obtaining and marketing this material.

Physical Properties of the Aggregate



Graphic 1. Granulometric curve of the sand.
Source: Authors of the project



Graphic 2. Granulometric curve of rubber fibers.
Source: Authors of the project

The materials used in the present investigation were subjected to different tests to obtain their properties.

Table II. Material Properties Summary Table.

MATERIAL	SPECIFIC WEIGHT (g/cm3)	ABSORPTION (%)	MOISTURE CONTENT (%)	LOOSE UNIT WEIGHT (g/cm³)	COMPACTED UNIT WEIGHT (g/cm³)
SAND	2,53	2,208	0,08	1,507	1,64
RUBBER FIBERS	-	-	-	0,40	1,62
CEMENT	-	-	-	0,92	-

Source: Authors of the project

Results:

The specific weight of the sand is shown in Table N°2, which shows an acceptable result in comparison to the recommendation of Porrero S. Ramos R [16], which indicates an optimal value for the fine and coarse aggregate of 2.5 to 2.7 of non-light aggregates, while a test was not carried out for rubber fibers due to the lack of regulations for our experimental material and complex composition.

According to the suggestion by the author Porrero S. Ramos R [16], the usual values of loose unit weight for coarse aggregate is from 1.4 to 1.5 and for fine aggregate is 1.5 to 1. 6, so that the coarse sand having a loose unit weight of 1,506 presents good characteristics, being necessary the determination of this value in the rubber fibers, taking into account that the size of the fibers range between 0.5 to 4 cm, which is necessary for the calculation of quantities for the elaboration of the present investigation. The usual compacted unit weight values for coarse aggregate are from 1.5 to 1.7 and for fine aggregate they are from 1.6 to 1.9, so the present fine aggregate has good characteristics.

Water

The water used was taken from the drinking water service network of the SEDAPAR company in the city of Arequipa.

Mix design

For the design of standard concrete (conventional concrete) and for the design of non-conventional concretes (with the addition of rubber fibers), compression tests of cubes of 5 cm on each side with different preliminary dosages are necessary to find the appropriate one. dosage for experimentation. Different tests were carried out with different amounts of cement-aggregate in 15%-85%, 25%-75%, 30%-70% (see Table N ° III), coinciding with the guide studies, it was conceived that the results were encouraging for a good dosage except for the mixture with 15% cement, this being very weak and inadequate for our study, being discarded.

Table III. Dosing of concrete cubes.

% Volume	P0	P1	P2	P3	P4
Fine Aggregate	100%	90%	85%	80%	70%
F. Rubber	0%	10%	15%	20%	30%

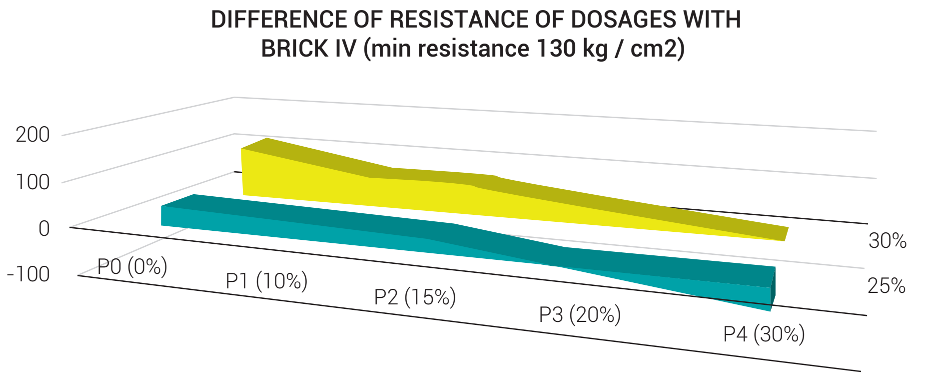
Source: Authors of the project

Knowing the optimal properties of our materials for our study, we proceeded with the design of the dosages by means of the experimental methodology, starting from a design basis already explained. By means of the compression test of cubes of 5 cm per side and in different dosages of rubber in the concrete, an optimal dosage was obtained at the age of 7, 14 and 28 days. The optimal design of the present study was obtained by varying the percentages of rubber fibers in replacement of fine aggregate in volume of 10, 15, 20 and 30% and with the constant amounts of cement in 25% and 30% in volume of base proportion P0.

Table IV. Difference of resistance of dosages with Types of brick according to resistance NTP-E070.

DOSAGE	25% CEMENT	30% CEMENT	BRICK IV (kg/cm²) 130		BRICK V (kg/cm²) 180	
			25%	30%	25%	30%
P0	171,40	248,22	41,40	118,22	-8,60	68,22
P1	164,58	201,32	34,58	71,32	-15,42	21,32
P2	155,93	194,60	25,93	64,60	-24,07	14,60
P3	119,50	155,73	-10,50	25,73	-60,50	-24,27
P4	84,50	131,06	-45,50	1,06	-95,50	-48,94

Source: Authors of the project



	P0 (0%)	P1 (10%)	P2 (15%)	P3 (20%)	P4 (30%)
25%	41,40	34,58	25,93	-10,50	-45,50
30%	118,22	71,32	64,60	25,73	1,06

Graphic 3. Difference of resistance of dosages with brick type IV.
Source: Authors of the project

The optimal dosage was chosen according to the analysis of compressive strengths and optimal densities, the best design option being the dosage of 25% cement - P2 with 15% rubber fibers replacing sand, having the strengths of 103,33 Kg/cm2, 123,69 Kg/cm2 and 155,90 Kg/cm2 at the ages of 7.14 and 28 days respectively and with a density of 1.92 g/cm3. The objective of the research is fulfilled by obtaining an economic material, with quality and ecological, being the dosage by weight of the materials used for the manufacture of a concrete masonry brick with recycled rubber fibers, considering 10% waste and complying with the characteristics of the masonry unit for structural purposes.

Table V. Classification of masonry units for structural purposes.

CLASS	VARIATION OF DIMENSIONS (maximum in percentages)			ALABEO (Max. in mm)	CHARACTERISTIC RESISTANCE TO COMPRESSION (minimum fb in Mpa (kg / cm²) over gross area
	Until 100mm	Until 150mm	More than 150 mm		
BRICK I	±8	±6	±4	10	4,9 (50)
BRICK II	±7	±6	±4	8	6,9 (70)
BRICK III	±5	±4	±3	6	9,3 (95)
BRICK IV	±4	±3	±2	4	1,27 (130)
BRICK V	±3	±2	±1	2	17,6 (180)
BLOCK P	±4	±3	±2	4	4,9 (50)
BLOCK NP	±7	±6	±4	8	2,0 (20)

Source: RNE norme E070.

3. RESULTS

a) Percentage of alveolar area.

Concrete bricks with RRB recycled rubber fibers meet the requirements for alveoli percentages by not exceeding 30% of the percentage of alveoli being considered as solid units, while the calcined clay brick KKH10 are considered as hollow unit when exceeding the established percentage.

Table VI. Table comparative percentage of alveoli.

BRICK TYPE	PERCENTAGE OF AREA OF ALVEOLES (%)
KKH10	31,5%
RRB TYPE I	29,6%
RRB TYPE II	26,9%

Source: Authors of the project

b) Dimensional variation test

Given the results of dimensional variability as shown in Table 7, RRB I brick is type IV, RRB II is type V and calcined clay brick is considered type IV.

Table VII. Table dimension variation summary

BRICK TYPE	VARIATION OF DIMENSIONS (% MAXIMUM)		
	Until 100mm	Until 150mm	Greater than 150 mm
KKH10	0,14	1,13	1,42
	TYPE V	TYPE V	TYPE IV
RRB TYPE I	3,93	1,12	0,16
	TYPE IV	TYPE V	TYPE V
RRB TYPE II	0,47	0,39	0,77
	TYPEV	TYPE V	TYPE V

Source: Authors of the project

c) Warping test

Considering the classification of masonry units of the E.070 standard, in the warping test the calcined clay unit KKH10 is classified as type IV, the RRB I unit as type IV and the RRB II unit as type V.

Table VIII. Roll summary table.

BRICK TYPE	Warp (Max. mm)
KKH10	2,55
	IV
RRB TYPE I	4
	IV
RRB TYPE II	2
	V

Source: Authors of the project

d) Absorption test

Table IX. Summary table of absorption.

BRICK TYPE	ABSORPTION (%)
KKH10	16,27
RRB TYPE I	3,81
RRB TYPE II	3,64

Source: Authors of the project

It is known that the units with absorption greater than 22% have higher porosity and low resistance to weathering, the percentages of CSF absorption being very low compared to the calcined clay KKH10 units that reach 16%.

e) Maximum absorption test

Table X. Summary table of maximum absorption.

BRICK TYPE	ABSORPTION MAX. (%)
KKH10	17,56
LCR TYPE I	4,61
LCR TYPE II	4,33

Source: Authors of the project

Like absorption, the maximum absorption data results indicate that RRB concrete bricks have low percentages compared to KKH10 calcined clay bricks.

f) Density test

Table XI. Density summary table

BRICK TYPE	DENSITY (g/cm^3)
KKH10	1,75
RRB TYPE I	1,92
RRB TYPE II	1,93

Source: Authors of the project

The densities obtained from the RRB were relatively positive compared to ordinary concrete, varying from 2.4 - 2.5, since low-density rubber fibers were included.

g) Suction test

Table XII. Suction summary table.

BRICK TYPE	SUCTION (g/cm^2*min)
KKH10	47,88
RRB TYPE I	12,95
RRB TYPE II	8,49

Source: Authors of the project

The suction test gave the following results for KKH10-47.88, RRBI-12.95 and LCRII-8.49, which shows the disadvantage of setting the calcined clay brick since it will subtract water from the mortar being necessary to use wet units in the laying of walls, such treatment is unnecessary in the laying of the RRB bricks.

h) Test of resistance to traction by bending or module of rupture.

The bending tensile test gives better results for the RRB I brick compared to the KKH10 calcined clay brick, due to the rubber fibers inside.

Table XIII. Bending tensile strength comparison table.

BRICK TYPE	f btf (kg/cm²)
KKH10	11,85
RRB TYPE I	11,96
RRB TYPE II	11,76

Source: Authors of the project

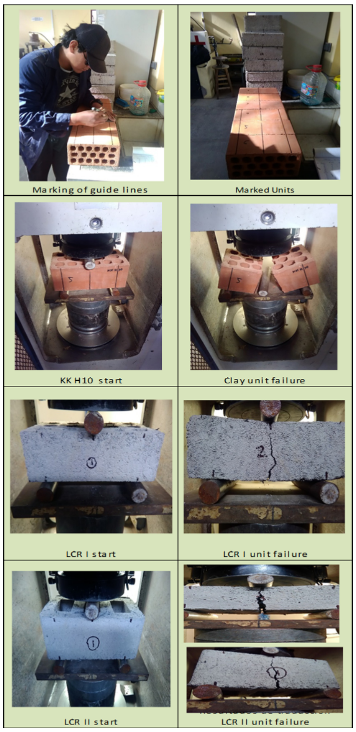


Figure 1. Test procedure.
Source: Authors of the project

i) Indirect traction test

The indirect tensile test shows that the RRB II brick is better than the calcined clay brick KKH10 by 0.6 kg/cm2 as shown in Table 14.

Table XIV. Indirect tensile strength comparative table

BRICK TYPE	f btf (kg/cm^2)
KKH10	4,13
LCR TYPE I	3,65
LCR TYPE II	4,70

Source: Authors of the project

j) Compression strength test

According to the results of the unit compression test, the RRB I unit is classified as type IV, the RRB II unit is classified as type III and the calcined clay unit KKH10 is classified as type IV.

Table XV. Comparison table of compressive strength.

BRICK TYPE	f b f (kg/cm^2)
KKH10	144,775
RRB TYPE I	130,320
RRB TYPE II	115,813

Source: Authors of the project

MASONRY PRISMS AND MURETS

k) Test of compression of masonry prisms

The compression results of masonry prisms indicate that those made with RRB units are better by approximately 14 kg/cm2 and 4 kg/cm2 than those made with KKH10 calcined clay units, according to the standard.

Table XVI. Comparison table of compressive strength of prisms.

BRICK TYPE	f´m (kg/cm²)
RRB I	78,38
RRB II	68,64
KKH10	64,19

Source: Authors of the project

l) Diagonal compression test of walls

The results of the diagonal compression test of walls corroborate a greater resistance for the RRB walls in approximately 2 kg/cm2 higher than the KKH10 calcined clay walls, meeting the requirements of the standard.

Table XVII. Diagonal compressive strength comparison table.

BRICK TYPE	V´m (kg/cm²)
RRB I	9,94
RRB II	8,03
KKH10	7,53

Source: Authors of the project

m) Axial compression test of prisms to obtain the elasticity module.

The modulus of elasticity is found for the experimental materials by means of prism compression, being lower, but not far from the value of the norm, which considers an ideal of 700 times f`m:

Table XVIII. Comparative table of modulus of elasticity.

BRICK TYPE	Em (kg/cm2)
RRB TEORICO (700 F m)	54866,74
RRB I	54006,73
RRB II	53453,23

Source: Authors of the project

n) Diagonal compression test of walls for calculating the cutting module.

The shear modulus was found thanks to the diagonal compression tests in the walls of the experimental material, obtaining lower values, but not far from the ideal according to the norm and bibliography that establishes it as 0.4 times E´m:

Table XIX. Shear modulus comparison table.

BRICK TYPE	Gm (kg/cm2)
RRB TEORICO (0.4 E´m)	21946,69
RRB I	21893,05
RRB II	21665,15

Source: Authors of the project

Figure 2. Wall test.
Source: Authors of the project

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BRICK COST ANALYSIS

Given that there are the necessary materials in the city and the proven quality of the experimental brick, then, the necessary quantification of materials will be shown for the elaboration of a concrete brick with rubber fibers from tires:

Table XX. Materials and cost of the LCR-I unit

LCR (unit)			
MATERIALS	**AMOUNT (Kg)**	**COSTS $**	**SUBTOTAL**
Cement	0,650	0,132	0,086
Rubber Fibers	0,130	0,079	0,010
Gross sand	2,710	0,007	0,019
Water	0,500	0,002	0,001
Workforce	1,000	0,135	0,135
			0,251

Source: Authors of the project

In the current market, the mechanized calcined clay brick KKH10 has a cost of 0.286 dollars, while the cost of the experimental RRB-I brick has a cost of 0.251 dollars, taking into account that this cost includes unskilled labor, and its yield is 80 units/day, costing 12% less than mechanized brick. It should be taken into account that the production of these RRB bricks will increase since it will be in charge of the population that in order to reduce costs will not skimp on working hours increasing their performance for their own well-being.

4. DISCUSSION AND CONCLUSIONS.

1. It was determined that the optimal dosage for the preparation of the RRB bricks in this study is the so-called P2 of constant proportions of 25% cement, 11.25% rubber fibers and 63.75% sand, being 15% the replacement of sand by rubber fibers, obtaining a compressive strength of 155 kg/cm2 and a density of 1.92 g/cm3 in the tested 5cm x 5cm x 5cm concrete cubes.
2. The rubber fibers produced in the retreading machines have advantages compared to the common sand that is used, since it has a loose unit weight of 0.4 g/cm3, therefore, 73.46% lighter than the common aggregate (coarse sand) that is used; in addition, the RRB unit has less absorption than the calcined clay unit.

3. The behavior of the rubber fibers in the RRB masonry units is beneficial by lowering the density while the percentage of rubber fibers increases up to 11.25% in volume, but it is also inversely proportional with its resistance to compression.
4. In the tests carried out on the RRB brick, optimal results were obtained 4 mm for warping, 0.16 mm for variation of dimensions, 3.81% for absorption, 1.92 g/cm3 for density and 130.320 kg/cm2 for compressive strength; demonstrating that RRB brick meets the requirements and can compete with a commercial brick like the KKH10.
5. Through the tests on the RRB I bricks, it was found that they meet the minimum requirements of the E070 Peruvian masonry standard and is classified as a class IV unit, as well as the mechanized calcined clay brick KKH10.
6. The compressive strength of RRB-I prisms is F´m: 78.38 kg/cm2, the diagonal compression resistance is V´m: 9.94 kg/cm2, showing that RRC-I bricks can be used in structural masonry with more specialized studies.
7. The optimal quantity for the elaboration of a RRB-I brick is 0.65 kg of cement, 2.72 kg of sand, 0.13 kg of tire rubber fibers and 0.5 l of water, being considered as handmade brick given its way of manufacture.
8. The RRB masonry units meet the minimum requirements established in the E070 Peruvian standard and have physical-mechanical properties that classify them as acceptable, demonstrating their benefits in the structural aspect, as well as in the environmental aspect, reducing pollution in the city of Arequipa. and benefiting the culture of research of materials for sustainable-ecological constructions.
9. The application of RRB bricks in the construction of basic housing modules as well as its massive artisanal manufacture, reduces costs significantly and provides security against any event due to its ability to break without instant or explosive failure as is the case of brick of handmade clay KKH10.
10. Rubber fibers from tires are a material produced in large quantities by the retreading machines of the city of Arequipa and it is recommended that it be used in the production of concrete bricks with rubber fibers since these materials are available in the city and they are not being exploited properly.

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