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Research Article

Physical and Mechanical Characterization of Concrete with Crushed Clay Brick with Mortar Attached for Irrigation Channels

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Abstract

The continuous population growth that has been taking place worlwide generates greater needs of people, the construction sector in response to this must act in harmony with the environment to build infrastructures and buildings; the latter being those that, due to the end of their life cycle or the interruption of their time of use and serviceability, require demolition. The materials obtained from this demolition are varied, highlighting the clay bricks that are presented in significant quantities, generating a problema that needs to be managed in a different way, due to their own characteristics inherent to their composition; an alternative solution is to recycle them to obtain recycled clay brick aggregates and use them in the elaboration of a recycled concrete of fc= 175N/mm2 that has good physical and mechanical performance. The present research contemplates the use of the recycled coarse aggregate of crushed brick with mortar attached 25mm Ø as a 75% replacement of the natural coarse aggregate, evaluating the density, voids, water absorption and compressive and flexural strengths to the 7, 14 and 28 days; the results indicate that density, voids, water absorption and the compressive and flexural strengths present a good physical and mechanical behavior, making it suitable to be used in the lining of irrigation channels.

Keywords: Crushed clay brick, Lining, Irrigation channels, Mortar attached, Physical and mechanical properties

1. Introduction

The current growth of the population requires that cities are planned with a greater number of urbanizations in response to the increase in buildings; which will generate a greater amount of construction and demolition waste that will continue to be treated through the waste hierarchy [1].

The building construction and demolition debris are composed of different materials with brick and clay tile, concrete, steel, drywall and plaster, asphalt shingle, and wool products; of which brick and clay tiles represent 12.3 million tons (6.5%), with 10.8 million tons destined for landfill and 1.5 million tons for aggregates and other uses [2].

These old and new buildings are demolished, after the selective deconstruction of components process, or directly; having as causes the end of service life, earthquakes, floods, wars [3], [4].

Within the waste from demolished brick walls, the main component is the clay brick [5], whose management in different parts of the world is carried out by direct disposal to landfills [6], [7], [8], [9], [10], [11], [12], [13], [14], [15] o illegal dump sites [16]. That is, when they are deposited in the landfill, they fill them sooner than the expected time in their design useful life, they contaminate the waste present because they are mixed with different contaminants such as bitumen, plaster, mortar, concrete, etc. Compaction is difficult due to its hardness and heterogeneous composition. In the same way, when they are deposited in unauthorized areas, there is an alteration of the land contaminating the groundwater and generating a very important visual impact for people.

A more up-to-date perception of the management of this waste has been considered in the European Union, within the 3R principle (Reduce, Reuse, Recycle), by including the circular economy model [17]; which considers the waste as a product that has an economic value, which is designed to be used again and thus enter to complete its life cycle. This new vision contributes to generating other business opportunities and attracting investors and entrepreneurs to conduct production, thereby promoting the generation of new jobs.

Under this approach, with the recycling of CB, mortars and concretes can be made, being able to be as a partial substitute for cement, and as a partial replacement for aggregates: fine, fine-coarse and coarse. That is, it decreases the dependency of natural raw materials [7], helps in the preservation of natural aggregate resources and contributes with the saving of water and energy required for its production process [18].

Some drawbacks of Recycled Aggregates of Crushed Clay Brick (RACCB) are: high voids [19], [20], fairly angular appearance, fairly smooth surfaces, high porosity, contains contaminants [20], lower density, high water absorption [21], [22], [18], low strength [22]. The concrete made with RACCB presents lower strength at early ages, higher strength at later ages [20] and its density is between 2000-2800 kg/m^3

In the production of fired CB, the firing process is the most important because the bricks hardens and acquires strength required for its use; in this stage calcination develops, which activates the clay and modifies its original crystalline structure, producing an increase in its pozzolanic activity [23], [24]; which allows the calcium hydroxide to be fixed in the presence of water to give hydrates similar to those of Portland cement [25]. These hydrates decrease the porosity of mortars and concretes [26] [25], which contributes to the durability of structures [25].

The irrigation channel is a permanent structure constructed to convey irrigation water from the source of supply to one or more irrigated areas [27], as part of its design, impermeability must be considered as an important requirement for the selection of lining; being the seepage control one of its functions that it must fulfill [29]. As an alternative material for the lining of these channels and that contributes to the reduction of water waste, the Crushed Clay Brick with Mortar Attached (CCBMA) is proposed as a partial replacement ofthe Natural Coarse Aggregate (NCA).

Some investigations have been reported on the use of Crushed Clay Brick (CCB) as a replacement for NCA in the preparation of concrete, and Brick Powder (BP) as a replacement for cement for the preparation of mortar, related to the properties in study. [21] indicates that the density of concrete with CCB decreases when the replacement percentage varies from 20%, 35%, 50%, 75% to 100%, this being 14.5% when going from 20% to 100%. In the case of voids, [29] comments that the mortar with 30% BP decreases when varying the test age from 1, 3, 7, 14 to 28 days of curing, this decrease being 48% when going from 1 to 28 days. For the water absorption, [21] indicates that the concrete with CCB increases by varying the replacement percentage from 20%, 35%, 50% to 100%, this increase being 123.1% when going from 20% to 100%.

Now, the compressive strength of concrete with 100% CCB increases with the test age for variations of 7, 14 to 28 days, this increase being 48% when passing from 7 to 28 days [30]. Similarly [29] found that the mortar with 30% BP increases when the test age varies from 7, 14, 28 to 70 days, this increase being 50% when passing from 7 to 70 days. On the other hand, [29] also studied the flexural strength of the mortar with 30% of BP, indicating that it increases by 10% after passing from 7 to 70 days.

This research contemplates the study of the high amounts of CB existing after the demolition of buildings. For this, the density, voids, water absorption, compressive strength and flexural strength at 7, 14 and 28 days have been studied of Concrete with Crushed Clay Brick Aggregate with Mortar Attached (CCCBAMA), which can be used in Lining of Irrigation Channels (LIC).

2. Materials And Method

Materials

a. Cement

Type I Portland Cement was used, according to specifications given by [31].

b. Aggregates

Fine (coarse sand) and coarse (crushed stone) 25mm natural aggregates were used, as well as recycled coarse aggregates crushed with 25mm attached mortar, from the demolition of 4 modules of CB walls (M1, M2, M3, M4). The characteristics of the aggregates used are shown in Fig. 1.

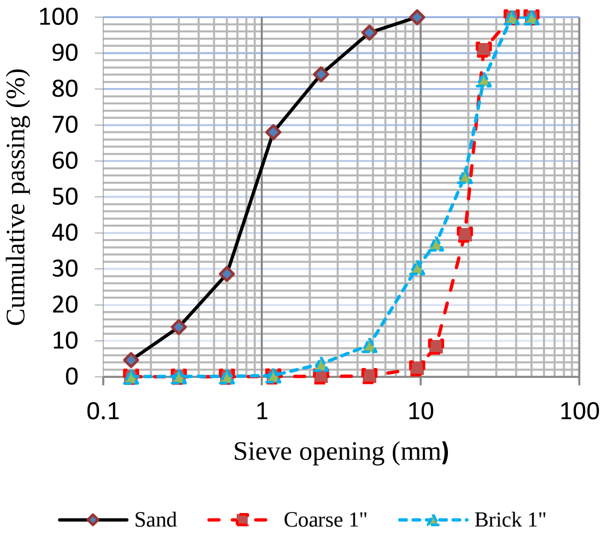

Fig. 1 Grading curves of fine and coarse aggregates

c. Water

For the preparation of the mixtures, drinking water was used that meets the characteristics of [32].

d. Bricks

2 types of CB were used: King Kong 18 hole perforated of 230mm (L) x125mm (W) x90mm (H) and Hollow of 230mm (L) x110mm (W) x93mm (H), which are shown in Fig 2.

e. Steel

It was used for the beam foundation and columns steel bars of 12.5mm and black tie wire 16 gauge.

f. Stone

19mm aggregate was used for the 0.23mx0.23m column and 12mm aggregate for the 0.13mx0.13m column, for the 0.50mx0.40m 25mm big stones foundation.

Method

The experimental tests have been carried out in 2stages for a CCCBAMA to achieve a 28-day compression strength of 17N/mm^2, in the first part a preliminary study was carried out, the influence of different variables associated with the composition of the mix on some properties; based on these preliminary results, one of the mixtures that had a better performance was chosen as a reference, which is shown in Table I. In the second stage, different physical and mechanical properties with a view to deepening the knowledge of this material for its use in (LIC). The recycled aggregates were obtained by crushing the CB with adhered mortar and then using a vibrating screen in the laboratory to obtain the different diameters to be used in the study.

TABLA I MATERIALS FOR 1 M^3 OF CONCRETE

Materials	Quantities (Kg)
Ordinary Portland Cement I	320
Natural sand	870
Natural gravel 25mm	235
Crushedclaybrick 25mm	573
Agua (l)	240

(a) (b)

Fig. 2 Types of clay brick: (a) 18 hole perforated (b) Hollow

The mixes were made and cured for 7, 14 and 28 days with [33] and then tested in a hardened state. The properties studied where: density, voids and water absorption [34], compressive strength [35] and flexural strength [36]; the number of specimens was 3, using 150mmx300mm cylinders, except for the flexural strength which were 150mmx150mmx500mm.

Wall Modules

In Fig. 3 shows the area where the M1, M2, M3 and M4 walls are located, which were built on a 0.25mx0.25mx2.40m foundation beam. M1 and M2 walls of 2.40mx0.23mx2. 40m, were braced with 2 columns of 0.23mx0.23mx3.20m; and the M3 and M4 walls of 2.65mx0.125mx2.40m and 2.68mx0.11mx2.40m were braced with 2 columns of 0.125mx0.125mx2.40m and 2 columns of 0.11mx0.11mx3.20m.

The characteristics of M1, M2, M3 and M4 are shown in Table II and in Fig. 4 and Fig. 5.

TABLA II MODULES CHARACTERISTICS M1, M2, M3, M4

Wall modules	Types ofbrick	Types of bonds	Mortar mixes (cement:sand)	Horizontal, vertical joints (mm)
M1	Holepeforated	Header	1:5	10
M2	Holepeforated	Header	1:5	15
M3	Hollow	Strecher	1:4	10
M4	Hollow	Strecher	1:4	15

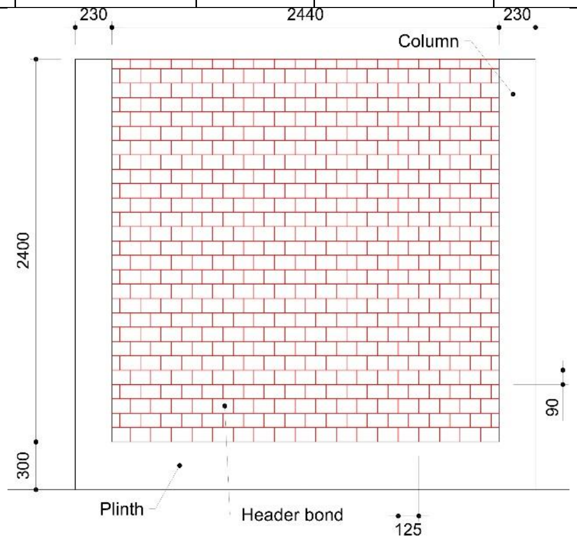

Fig. 4 Clay brick modules M1, M2

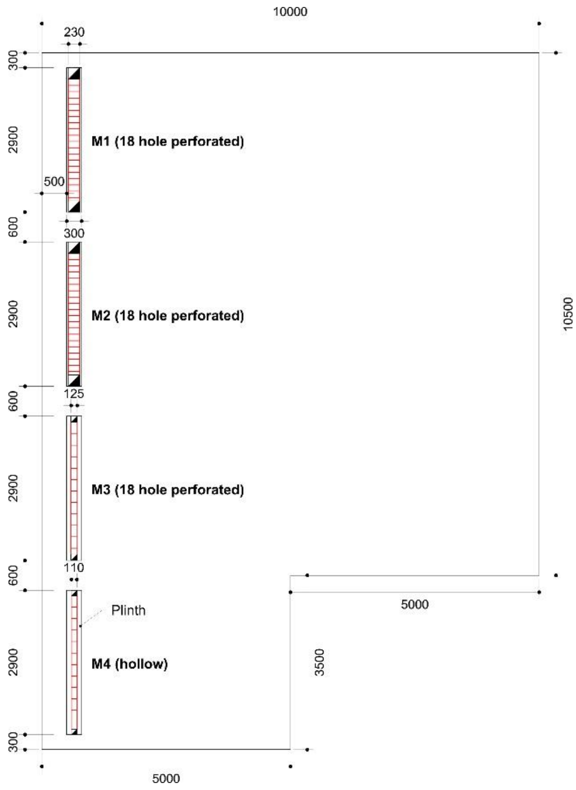

Fig. 3 Brickwalls modules plan

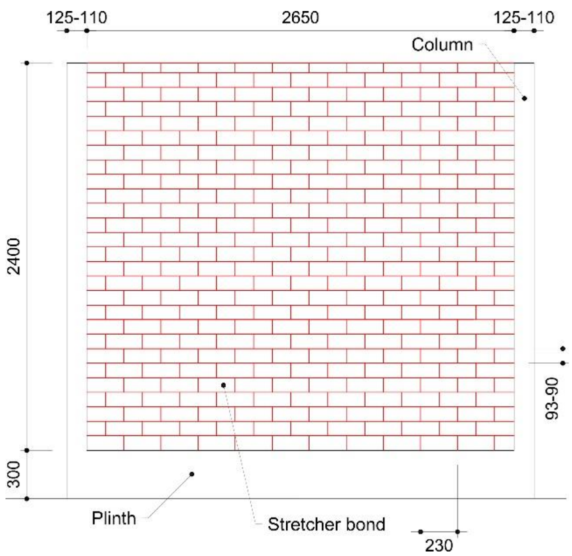

Fig. 5 Clay brick modules M3, M4

3. Results

Density

In Fig. 5 the influence of concrete age on density is shown, where it is observed that by varying age the density increases, reaching the values of 2.13kg/m^3 and 2.16kg/m^3 for the ages of 14 and 28 days that are equivalent to 11.0% and 2.4% more than the age of 7 days to which the value of 2.11kg/m^3 corresponds.

Voids

In Fig. 6 the influence of the age of the concrete on the voids can be seen, where it is observed that by varying age the voids decrease, obtaining the values of 12.26% and 9.10% for the ages of 14 and 28 days that are equivalent to 115.4% and 37.2% less than the age of 7 days at which the value of 14.50% corresponds to it.

Water Absorption

In Fig. 7 the influence of concrete age on water absorption is shown, where it is observed that by varying age the water absorption decreases, reaching the values of 5.75% and 4.22% for the ages of 14 and 28 days that are equivalent to 116.4% and 38.7% less than the age of 7 days at the which corresponds to the value of 6.88%.

Compressive Strength

In Fig. 8 the influence of the age of the concrete on the compressive strength is appreciated, where it is observed that by varying age the compressive strength increases, reaching the values of 22.0N/mm^2 and 23.3N/mm^2 for the ages of 14 and 28 days, which are equivalent to 16.4% and 12.5% more than age. of 7 days to which the value of 20.7/mm^2 corresponds.

Flexural Strength

In Fig. 9 the influence of concrete age on flexural strength is shown, where it is observed that by varying age the flexural strength increases, reaching the values of 2.9N/mm^2 and 3.0N/mm^2 for the ages of 14 and 28 days that are equivalent to 15.0% and 8.3% more than age of 7 days to which the value of 2.7N/mm^2 corresponds.

4. Discussion

Density

Reference [37] study the variation of mortar at 3, 7 and 28 days for 20% limestone as a replacement for cement, finding the values of 2,160kg/m^3, 2,165kg/m^3 and 2,185kg/m^3 respectively, these being 0.2% and 1.2% higher than density at 3 days. On the other hand, the authors [38] studied the variation of the mortar at 7, 28 and 90 days using 15% metakaolin as partial cement replacement, finding the values of 2.102kg/m^3, 2.115kg/m^3 and 2.126kg/m^3, these being higher by 0.80% and 1.47% with respect to the density at 7 days. This behavior of increased resistance is due to the fact that there is a gradual filling of large pores by the hydration products [39] that favors the reduction of the specific surface area of Calcium-Silicate-Hydrate (C-S-H) with time that produces an increase in density of the hydration product [40].

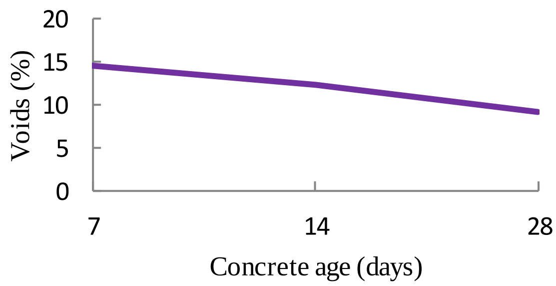

Fig. 6 Influence of concrete age on voids

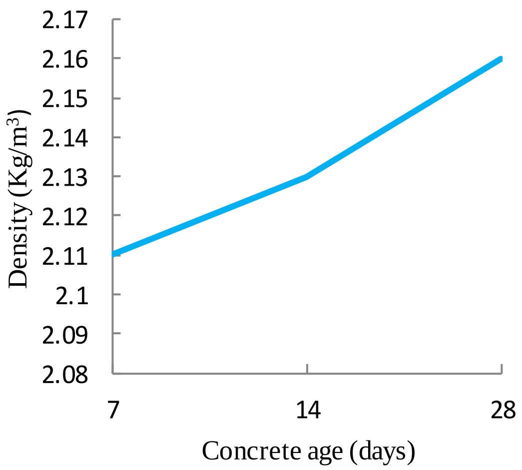

Fig. 5 Influence of concrete age on density

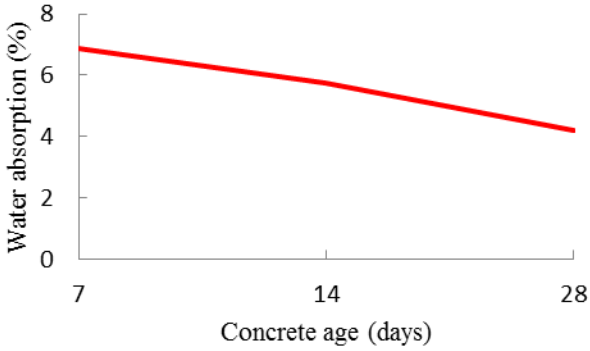

Fig. 7 Influence of concrete age on water absorption

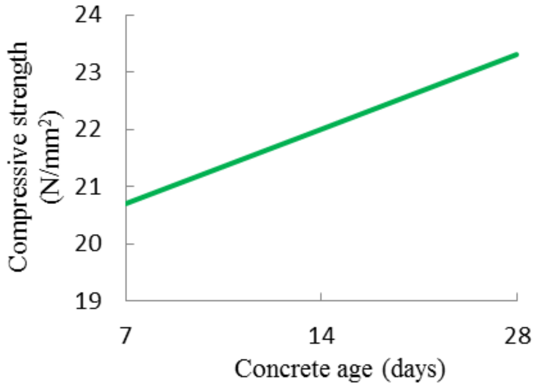

Fig. 8 Influence of concrete age on compressive strength

Voids

Reference [41] studied the variation of concrete at 7 and 28 days for a / c = 0.55 and used CB aggregate, finding the values of 18.08% and 16.84% respectively, this being less by 6.9%. On the other hand, the authors [38] studied the variation of the mortar at 7, 28 and 90 days using 15% metakaolin as partial cement replacement, finding the values of 20.5%, 20.0% and 18.8%, these being lower in 2.4% and 8.3% with respect to voids at 7 days. This void decrease behavior could be because there is a progressive reduction of the amount and connectivity of capillary porosity within the cement matrix.

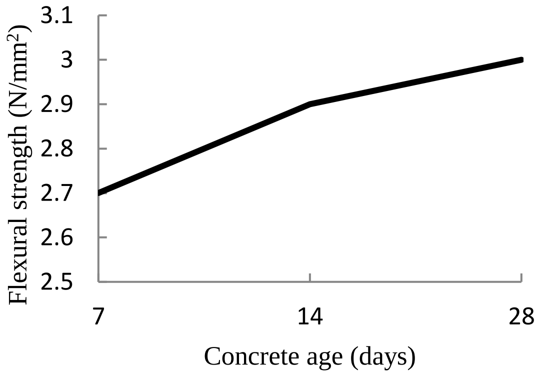

Fig. 9 Influence of concrete age on flexural strength

Water Absorption

Reference [42] studies the variation of the mortar at 7 and 28 days for 20% of Ground Clay Brick as a replacement for cement, finding the values of 8.43% and 7.74% respectively, being this lower by 8.2% with respect to the absorption after 7 days. On the other hand, the authors [43] studied the variation of concrete with recycled brick aggregates with partial saturated surface dry, replacing 50% of natural sand, for a / c = 0.55 and tests at 28 and 90 days, finding the values of 5.75% and 5.10%, this being 11.3% lower than absorption at 28 days. This behavior of decreased water absorption could be because the increase of pore refinement over time contributes to the reduction of the volume of open porosity of concrete.

Compressive Strength

Reference [44] studied the variation of concrete at 7 and 28 days for an a / c = 0.50, 455Kg/m^3 of cement and used CCB obtained from an industrial brick waste plant of ¾" with 75% replacement of the natural coarse aggregate, finding the values of 38.2N/mm^2 and 46.2N/mm^{2}measured in cubic specimens of 150mx150mx150mm, being this greater by 21.1% higher than the 7-day resistance. On the other hand, the authors [45] studied the variation of concrete at 7, 14 and 28 days for an a/c = 0.55, 300Kg/m^3 of cement and used new solid common CB of ¾", finding the values of 23.5N/mm^2, 27.7N/mm^2 and 36.9N/mm^2, these being 11.5% and 30.8% higher than the 7-day resistance. The exposed results show the same tendency as those shown in the present work, these being lower, which would be related mainly to the mortar adhered to the aggregate used; which produces a weak new interfacial transition zone between the bonded mortar and the new paste, which causes a low resistance [46]. This resistance increase behavior could be because the reaction mechanism between lime and calcined clay produces a progressive increase in C-S-H gel that causes a pore blocking and pore refinement, causing a lower total pore volume.

Flexural Strength

Reference [47] studied the variation of concrete at 7 and 28 days for a/c = 0.47 and used 20% CCB aggregates and 80% recycled concrete aggregates, finding the values of 0.37N/cm^2 and 0.40N/mm^2 respectively, this being higher by 9.0% than the 7-day resistance. On the other hand, the authors [48] studied the variation of concrete with CBaggregate at 7 and 28 days for a/c = 0.66, finding the values of 17.06N/mm^2 and 20.69N/mm^2, this being higher in 21.3% from the 7-day resistance. The results presented show the same tendency as those shown in the present work, being these a little higher. This behavior of increasing resistance, like the compressive strength, could be because the SiO_2 and Al_2O_3 present in the calcined clay react with the hydrated cement paste consuming calcim hydroxide and produces as a substantial amount of C-S-H gel that originates less pore structure.

5. Conclusions

The 75% CCBMAused as a replacement for NCAproduces concrete with good physical and mechanical performance and is suitable for use in the lining of irrigation channels.

The decrease in CCCBAMAvoids is related to the continuous precipitation of more hydration products within the pore system.

The low voids and water absorption of the CCCBAMAfound favor the formation of a dense concrete microstructure.

The values obtained for the density, voids and absorption water indicate that the CCCBAMA has adequate durability.

The decrease of porosity and pore size distribution of hydrated cement paste produce an increase in the compressive strength and flexural strength of the CCCBAMA.

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