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Use of recycled broken bricks as *Partial Replacement Coarse Aggregate* for the Manufacturing of Sustainable Concrete

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Abstract. The bricks are one of the primary materials required for construction of homes that no used completely when executes all the walls due, the excess purchase, the cutting to be settle, the breaking for their transfer and its fixed dimensions; this situation requires monitoring on work site the order, cleanliness and accidents. A common practice is these bricks and/or waste are included in the clearing construction before being deposited or eliminated in dumps or sanitary landfills, with their early clogging and shortening them to ther design lifespan. An important alternative to reduce this waste, is to recycle them and reuse them as a concrete component material, due to their high absorption percentage that allows them to keep the water inside of them and then use it in the cement hydration process as internal curing of the concrete. In the present investigation, the effect of crushed clay brick as a replacement for coarse aggregate in concrete processing is studied. The results indicate that with 21 % replacement brick, the plastic contraction decreases, and the compressive strength and flexural strength increase.

1. Introduction

Nowadays one of the main concerns around the world is environmental pollution, where the construction industry is the one that produces a high impact on the atmosphere and natural resources, due to the high consumption of raw materials, being one of the main waste sources of building materials [1]. This waste, in the case of brick in the construction of multifamily buildings, is estimated in Britain in 380000 tons and in the United States in 120000 tons [2]. Studies by [3] in Hong Kong shows that the waste brick unused in the walls and masonry is between 4-8%. As a mitigation measure, it is proposed to associate the use of brick waste in the elaboration of a lightweight aggregate to later form part of the mixture, and thereby promote the sustainability of concrete. Lightweight aggregates are generally porous and can absorb a considerable amount of water when immersed in it [4]. The clay brick has a high water absorption capacity due to its capillarity, which is directly related to its internal pores that make it variable depending on its quantity, size and shape; being this, an important physical property of the brick to be taken into account in the internal curing of the concrete. [5] performs tests with crushed brick as coarse aggregate and finds that this material has an absorption percentage of 9.90%. In this sence, here, [6] proposes the use of crushed brick for its effectiveness as a means of internal curing, based on their experiments suggest using 20% of crushed brick as replacement thick aggregate to achieve a resistance to the compression greater. Some researchers have experimented with lightweight aggregates and [5] evaluates different concrete mixtures with 10%, 20, 30% replacement of broken brick and obtains a decrease from 2% - 6% of the resistance the compression and concluded that their results are similar to control concrete and that it is feasible to use the broken brick. Regarding the flexural strength, it shows a decrease in resistance between 0% - 2%, which represents a behaviour similar to the control concrete. Similarly, Rajamanickam [7] studies light expanded clay (LECA) as a replacement for natural aggregate, finding that the compressive strength of concrete with LECA is less than 7 days than control concrete. In the case of 28 days, with a 15% replacement of LECA, it is obtained that the compressive strength is 1.84% more than the control concrete due to the presence of an adequate moisture content in the aggregate; for a percentage greater than 15% the resistance decreases due to the weaker nature or the very pronounced water absorption characteristics of the aggregate. In this paper we study the influence of crushed brick clay as partial replacement of coarse aggregate in making concrete by plastic shrinkage, the compressive strength and flexural strength.

2. Materials y methods

2.1. Materials
The crushed brick used has a Ø 3/4“, the cement is the Portland Type I brand Sol, the aggregates used are coarse sand and natural stone of Ø 3/4“, the water was drinkable.

2.2. Method
The mix design was made for a particular f’c= 280 Kg/cm2 according to the Fineness Modulus of the Combination of Aggregates [8], the brick ground is saturated for 24 hours. Table 1 shows the designs of the mixtures carried out and Table 2 shows the tests performed and the number of samples used.

Table 1. Dosage for concrete designs in a cubic meter.

Components	Control	Design 1 brick 15%	Design 2 brick 21%	Design 3 brick 27%
a/c ratio	0.50	0.50	0.50	0.50
Water	178.30	193.10	193.10	193.10
Cement	390.00	390.00	390.00	390.00
Coarse aggregate	918.10	780.40	725.30	670.21
Fine aggregate	750.60	750.60	750.60	750.60
Crushed brick	0.00	113.40	192.80	247.88

Table 2. Tests performed

Essays	Applicable standard	N°. tests	Cure age (days)
Plastic shrinkage	ASTM C 1579 [9]	3	1
Compressive strength	ASTM C39 [10]	9	7, 21, 28
Flexural strength	ASTMC 78 [11]	3	28

3. Results and Analysis

3.1. Plastic shrinkage
In the Table 3 the influence of crack initiation time of crack width for design 2 and control mixture shown, and the reduction ratio of fissure (CRR). In it you can see that as the drying time increases the crack width and CRR grow, reaching for Design 2 the maximum value of 0.508 mm, which represents 38% less with respect to the control mixture for a time of 1440 min; achieving for this maximum value a CRR ratio of 37.50%. [12], [13] relate this behaviour to the degree of saturation of the aggregate,

which in the case of recycled aggregates for the condition of superficially dry saturates, the crack start time and the crack width increase.

Table 3. Crack width, drying time and CRR factor (Cracking reduction ratio)

Fissure initiation time (min)	Crack Width (mm)		
	Control	Design 2	CRR (%)
0	0.00	0.00	0.00
30	0.00	0.00	0.00
60	0.058	0.058	0.00
90	0.2932	0.1524	25.00
120	0.3048	0.2540	16.67
150	0.4572	0.3556	22.22
180	0.6604	0.4064	38.46
1440	0.8128	0.508	37.50

3.2. Compressive strength

The influence of the test age on the compressive strength of concrete for 0%, 15%, 21% and 27% of crushed brick is shown in Figure 1. In it can see that as the test age varies, the compressive strength increases, this being maximum for 21% of crushed brick at the age of 28 days, reaching the value of 355.55 kg/cm2, which represents a 4.07 % more with respect to the control sample. [6] study the clay splinter with replacements of 10%, 20% and 25%, obtaining that the specimens cured 7 days in water and 21 days in the laboratory without plastic coverage for a 20% partial replacement reach a resistance of 25% more than the control mixture, then decreases for a value of 30% partial replacement. [2] they study the clay splinter with replacements of 10%, 20% and 25%, obtaining that the specimens cured for 28 days in the laboratory without plastic coverage and with a 20% partial replacement reach a resistance greater than 4.6% with respect to the control mixture, from there the resistance drops for a 30% partial replacement. These growth trends are like those obtained in the study [14] indicates that this behaviour is due to the continuous hydration of the mixture at older ages, promoted by the extra water stored in the light aggregate.

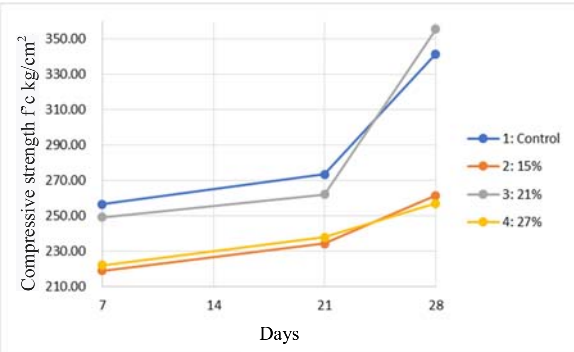

Figure 1. Influence of the test age on crushed brick compressive strength

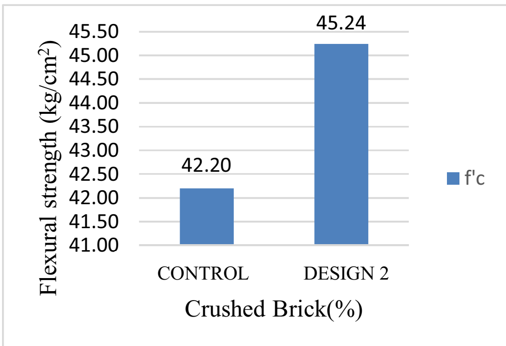

Figure 2. Influence of the percentage of on the resistance to bending

Table 4. Unit price analysis of control and design mix 2 per m^3

Materials	Unit	Control design			Design 2		
		Metrado	U.P.	Partial	Metrado	P.U.	Partial
Water	m^3	0.20	2.83	0.57	0.20	2.83	0.57
Cement	bls	9.18	22.20	203.80	9.18	22.20	203.80
Coarse aggregate	kg	884.10	0.14	123.77	725.30	0.14	101.54
Crushed brick	kg	0.00	0.00	0.00	158.80	0.23	36.52
Fine aggregate	kg	750.60	0.15	112.59	750.60	0.15	112.59
Mix workforce	hh	2.00	15.00	30.00	3.00	15.00	45.00
Trompo (70 lt)	hm	1.00	4.02	4.02	1.00	4.02	4.02
Workforce (cured)	hh	0.50	15.00	7.50	0.00	0.00	0.00
Water (cured)	m^2	1.00	2.83	2.83	0.00	0.00	0.00
Maintenance crack	m^3	1.00	76.00	76.00	0.00	0.00	0.00
TOTAL				561.08			504.04

3.3. Flexural strength

Figure 2 shows the influence of the percentage of crushed brick on the flexural strength at 28 days. In it you can see that with design 2 a value of 45.24 Kg/cm2 is reached, this being 7% higher than the control mixture. [15] studies the brick with recycled fine aggregate and finds that with 55% recycled fine aggregate 17.9% more is obtained than the control brick.

3.4. Cost evaluation

Table 4 shows the unit price analysis of the control mix and design 2 for 1 m^3 of concrete. As it can be seen, the variation in cost for design 2 is S/. 57.04 ($ 17.04 US dollars) of lower cost, which represents 10.17%, so design 2 is a cheaper alternative as a replacement for coarse aggregate with crushed brick. [2] they concluded that using partial replacement of coarse aggregate by saturated clay chips, is achieved decreases go using water and coarse aggregate, causing the unit price of concrete is reduced and is a good cost - effective alternative.

4. Conclusions

- The mixture with 21% crushed clay brick as a replacement for coarse aggregate has an average resistance of 5% and a lower cost that makes it possible to prepare a sustainable concrete.
- With the processed concrete, a reduction of cracks of 47% of the control sample is achieved because the good absorption capacity of the clay brick facilitates self-curing.
- The reuse of clay bricks from homes, and / or their waste, in the preparation of concrete contribute to the improvement of cement hydration.

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