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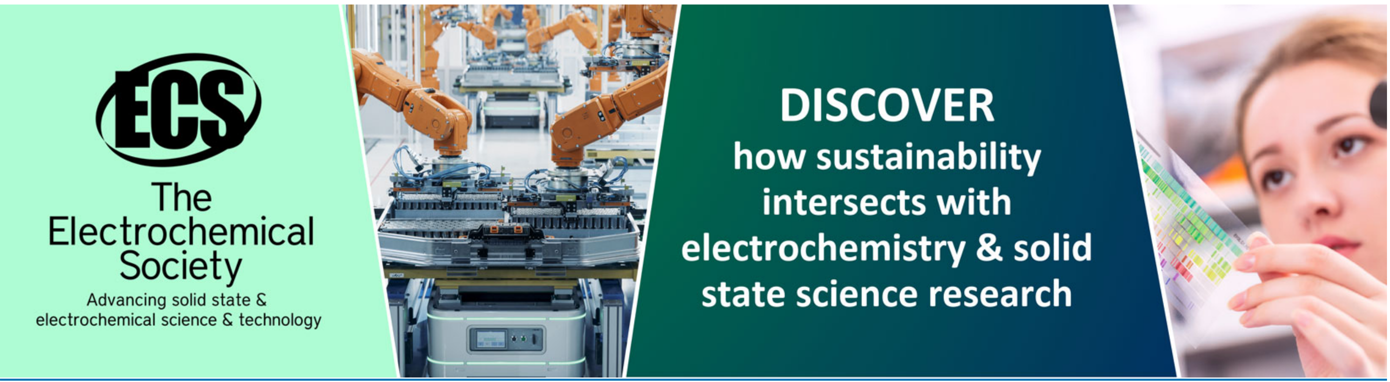

Low Permeability Concrete for *Buildings Located in Marine Atmosphere Zone* using Clay Brick Powder

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Abstract. The concrete is not one hundred percent impermeable since the water that remains inside it causes its corrosion, in the case of reinforced concrete, exposed in an area of marine atmosphere, the sea salt mostly present in large particles of the marine spray, produce the reduction of the alkalinity of the concrete causing a rapid corrosion of the steel. There are buildings built in this marine area that have been designed without durability criteria, in which the use of pozzolanic materials is considered, for example, to fill the pores of the cement matrix and thus guarantee its impermeability. In the present study, the effect of clay brick powder (PLA) as a replacement for cement in concrete manufacturing is addressed, evaluating different characteristics of its components. The results indicate that pozzolanic activity and compressive strength increase, slump, voids content and the coefficient of permeability to water decreases.

1. Introduction
A durable concrete is one that has a dense structure with minimal total porosity and low permeability [1]; this being important in the concrete exposed to the water of the sea, because it delays the effect of sulfate attack and guarantees a minimum coating of steel [2]. The marine environment has different exposure areas of expure that influence the deterioration of concrete structures, being the marine atmosphere where the marine aerosol is formed and there is produces an increase in the concentration of salts that are transported inland [3]; these salts are less than 10 µm (floating and don't settle) and greater than 10 µm (precipitate), these being the ones that cause corrosion of the steel located a few hundred meters to the inland of the coast [4]. To minimize this corrosion, low permeability concrete made with calcined clay is used as a partial cement replacement [5]. Clay brick is used in massively in small and large-scale construction projects, with the worldwide annual production of 1391 billion [6]. In its, operations are carried out with high energy consumption, very polluting and harmful to the environment [7], recycling is done in small quantities [8]; some of the important environmental impacts tare the reduction of the natural soil level [9] and the generation of solid waste [10]. The use of cement has improved living conditions for humans, but it has also brought tremendous pressure on the energy supply and ecological environments [11], its production in 2018 was 4.1 billion metric tons [12] and during its production there are different air emissions that pollute the environment, such is the case for example of CO_2 that is responsible for global warming [13], [14]. Given this situation, an interesting alternative is to use PLA because to having a high porosity, high water absorption and is a used as an addition to cement [15]. The objective of this work is to study the influence of the percentage of PLA as a replacement for cement for the construction of buildings built in an area of

marine environment addressing the study of pozzolanic activity, slump, compressive strength, voids content and coefficient of permeability to water.

2. Materials and Method

2.1 Materials

The cement is Andino Ultra HS; brick dust (PLA), its composition is shown in Table 1; the natural aggregates thick (19.5 mm) and fine are from the "Laura" quarry, their physical properties are shown in Table 2; the additive used was a Superplasticizer-Water Reducer; And the water was drinkable.

2.2 Method

For the pozzolanic activity index, 5 cm x 5 cm mortar cubes were prepared with 450 g of Sand and 112.5 ml of Water, using: for the MPLA-20 sample, 168.75 g (80% cement), 56.25 g (20% PLA); and for the MPLA-0 sample, 225 g (100% cement), for the calculation of the pozzolanic activity index. The mix design was made for a concrete f'c = 300 Kg / cm^2 according to [16]. 5 dosages were made with 0%, 5%, 15%, 25% and 30% of PLA, called CPLA-0 (standard mixture), CPLA-5, CPLA-15, CPLA-25 and CPLA-30 shown in the Table 1; the specimens after processing were demolded after 24 hours (Fig. 1) and then tested according to Table 2.

Table 1. Concrete mix design with f'_c= 300 kg/cm^2

Mix	Quantities in Kg for each cubic meter						
	W/C	Replacement PLA	Cement	Sand	Stone	Water	Super-plasticizer (ml)
CPLA-0	0.5	-	13.237	23.847	24.986	6.624	-
CPLA-5	0.512	0.962	12.575	23.588	24.715	6.443	151
CPLA-15	0.514	2.286	11.252	23.041	24.171	5.781	180
CPLA-25	0.516	3.609	9.928	22.523	23.628	5.119	200
CPLA-30	0.517	4.271	9.266	22.264	23.356	4.788	204

Table 2. Test performed

Test type	Days	Method	Measurement of samples	N °of specimens for test
Pozzolanic activity index	7, 28	[17]	5 cm x 5cm	3
Slump	-	[18]	-	-
Compressive strength	7, 14, 28	[19]	15 cm x 30 cm	3
Voids content	60	[20]	15 cm x 50 cm	1
Coefficient of permeability to water	60	[21]	15 cm x 20 cm	1

3. Results and Analysis

3.1. Pozzolanic Activity Index

Table 3 shows the effect of cure time on the pozzolanic activity index (IAP) for the MPLA-20 sample. It is seen that when the cure time varies, the IAP increases, reaching the value of 77.83% at 7 days and 171.08% at 28 days, giving an increase of 54.51% in relation to 7 days. As the IAP values for 7 and 28 days are greater than 75%, we conclude that MPLA-20 is a pozzolan. [22], evaluates the replacement of 20% of PLA in mortar, finding that the IAP for 7 and 28 days presents percentages of 100% and 101%, stating that it is a pozzolanic material (> 75%); The same author concludes that the content of PLA is sufficient for the hydration of the cement, that is, the formation of calcium hydroxide, silicate and aluminate improve the resistance properties. [23] also evaluates the replacement of 25% of PLA in the mortar finding that after 28 days the IAP is 100%, being considered a pozzolanic material (> 75%).

3.2. Slump
Table 4 shows the effect of the percentage of PLA addition on the settlement, it can be seen that the settlement decreases as the percentage increases, with decreases of 1.1" (16.92%) for the CPLA-30 and 0.5" sample (7.69%) for CPLA-25, CPLA-15 and CPLA-5, all these with respect to CPLA-0. [24], studies the settlement for different replacement percentages of ground PLA, finding that with 10% and 30% the settlement decreases by 2" and 5" with respect to the pattern; This behavior is due to the high absorption of the PLA which, by absorbing the water in the mixture, reduces its fluidity, so that its settlement is less and consequently the mixture is pasty and less workable. [25], evaluates the settlement for replacements of 20% and 100% of PLA in the form of coarse aggregate, obtaining a decrease of 0.01" and 0.7" for samples with 20% and 100%.

Table 3. Effect of curing time on pozzolanic activity index

	Compressive Strength (Pa)		Pozzolanic Activity Index (%)
Curing time	MPLA-0	MPLA-20	MPLA-20
7	19.888	39.729	77.83
28	15.479	67.968	171.08

3.3. *Compressive Strength*
Fig. 2 shows the effect of the test age on the compressive strength for different percentages of PLA. It ́s observed that the compressive strength increases with the test age, obtaining a maximum resistance value at 28 days of 36.40 MPa for CPLA-25, representing a 28.39% increase with respect to CPLA-0; and for CPLA-30 the value of 14.53MPa is reached, which represents a decrease of 48.76% with respect to CPLA-0. [26] carries out tests with 10%, 20% and 30% of PLA for 7, 14 and 28 days, finding that resistance increases with age and that after 28 days with 20% of PLA resistance increases by 8.24% compared to the standard concrete, and with 30% PLA the resistance drops by 3.70%. [27], for a 25% replacement of PLA as a 5mm fine aggregate, it expresses a slight increase of 6% and 9% at 28 and 90 days respectively compared to the standard sample. However, for a 50% replacement, a decrease of 4.4% is observed for 28 days and 8% for 90 days. [28] says, that the increase in resistance with age is due, having more water storage, the particles take time to achieve adequate hydration, however, this result changes when of curing increase, reducing internal stress and contraction effects.

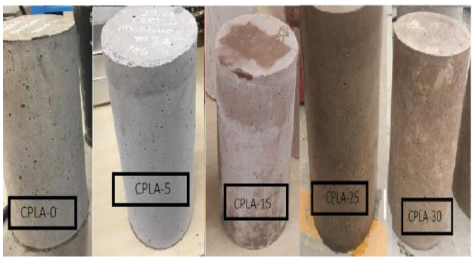

Figure 1. Specimens of concrete of 15 cm x 30 cm with PLA

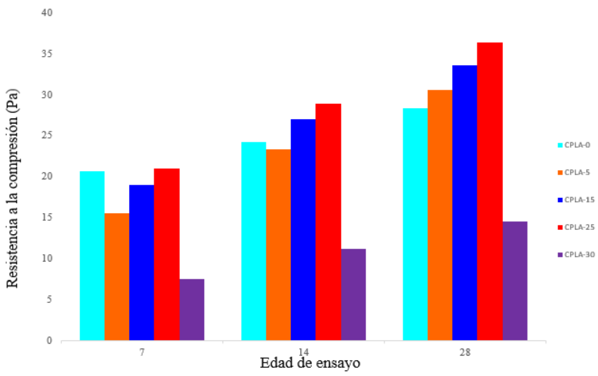

Figure 2. Effect of test age on compressive strength

3.4. Voids Content
Table 4 shows the effect of the percentage of PLA addition on the void content. Appreciating that as the PLA is increased to the mixture CPLA-5 and CPLA-25 the voids decrease and then increase for the mixture CPLA-30; reaching the highest decrease value of 13.40% and 20.80%, which represent - 8.84% and + 41.50% compared to CPLA-0. [29] evaluating the PLA for replacements of 10% and 20%, finds that the void content decreases 0.1% and 5% with respect to the pattern; this behavior is due to the finer particles of the brick filling the spaces left by the other materials reducing the volume

of pores; also, the reaction of silica and alumina with calcium hydroxide generates silicon and aluminate that improve the structure. [30], studies the gaps for 25% and 50% replacements of clay brick, obtaining a decrease of -1% of gaps for 25% an increase of + 1% for 50% compared to the control; concludes that, the higher the brick content, the greater the increase in voids and density.

3.5. Coefficient of permeability to water

Table 4 shows the effect of the percentage of PLA on the coefficient of permeability to water (K) at 60 days. It is seen that as the PLA increases, K decreases by 1.07% and 1.78% for CPLA-5 and CPLA-25 with respect to CPL-0, reaching a low permeability; then increases the K to 5.07x10-11, representing an increase of 94.57% with respect to CPLA-0 and for an average permeability. [31] studies the K of a mixture with superplasticizer, coarse and fine brick aggregate, finding a reduction of 84% over the pattern; This behavior is because the superplasticizer affects the concrete, reducing the K and increasing its durability. [32] replaces 0, 40% and 100% to PLA at 28 days, finding that 40% and 100% of PLA increase by 109% and 179% over the pattern; This behavior is because PLA has a higher pozzolanic activity and that its smaller particle improves the density and properties of the mixture. [33] evaluates the replacement of 100% fine brick aggregate at 28 and 91 days, obtaining a decrease of 58% and 57% of K with the pattern; this is due to the pozzolanic reactions between the aggregate and the cement; that is, the chemical reaction of aluminum and brick silica with calcium from cement hydration, generates hydrated monosulfoaluminate, which together with the formation of calcium silicate hydrate gel decrease chloride penetration.

Table 4. Properties of concrete with influence of PLA

Mix	Settlement	Void Content	Coefficient of permeability to water (m/s)	Permeability
CPLA-0	6.5"	14.70%	2.81E-12	Low
CPLA-5	6"	14.62%	2.78E-12	Low
CPLA-15	6"	-	-	-
CPLA-25	6"	13.40%	2.76E-12	Low
CPLA-30	5.4"	20.80%	5.07E-11	Average

4. Conclusions

- The pozzolanic activity of the mortar increases what indicates that the behavior is uniform and positive of the cement with the PLA.
- The slump of the mixture decreases slightly due to the absorption of water presented by the PLA, making it a little less workable.
- The compressive strength increases for 25% of PLA which means that it can be used in buildings in an area of marine atmosphere.
- The voids content decreases due to the pozzolanicity of the PLA, which indicates that it´s suitable for making a waterproof concrete.
- The coefficient of permeability to water decreases which means that a concrete with good durability can be prepared.

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