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Incorporation of crushed tetra pak in the manufacture of mortar

Incorporação de tetra pak triturado na fabricação de argamassa

Víctor Valério Landim da Silva[1*]

1 Engenheiro Civil, Mestre em Ciência e Engenharia de Materiais, Docente, Instituto Federal do Paraná – Campus Umuarama- Umuarama-PR . E-mail: victorvlandim@gmail.com
* Autor para Correspondência

RESUMO

Introdução: A utilização de materiais reciclados no processo construtivo, reduz a demanda por insumos não renováveis, além de reduzir a pressão ambiental nas áreas destinadas ao descarte sendo uma alternativa de uso de materiais convencionais.
Objetivo: Promover a adição de tetra pak triturado em substituição ao cimento (insumo que provoca grande impacto ambiental) na produção de argamassas sustentáveis, estudando a possibilidade de criar um produto mais resistente e reduzindo o impacto ambiental pelo lançamento destes produtos na natureza.
Metodologia: No Laboratório de Análise de Solos no Campus Cajazeiras-IFPB, foi feita a análise do comportamento das propriedades físicas do solo selecionado em busca da granulometria ideal. Os resultados foram comparados por curvas granulométricas de referências e analisados de acordo com as normas da ABNT, chegando assim a um produto com resistência considerável.
Conclusões: Torna-se relevante a utilização dos recursos disponíveis a realidade de cada região, de forma a auxiliar no desenvolvimento de materiais tecnicamente viáveis e ecologicamente corretos.

Palavras-chave: Tetra Pak, Argamassa, Sustentabilidade

ABSTRACT

Background: The use of recycled materials in the construction process reduces the demand for non-renewable inputs,in addition to reducing environmental pressure in areas destined for disposal, being an alternative to theuse of conventional materials.
Objective: Promote the addition of crushed tetra pak to replace cement (an input that causes a great environmental impact) in the production of sustainablemortars, studying the possibility of creating a more resistant product and reducing the environmental impact by launching these products in nature.
Methodology: In the Laboratory of Soil Analysis at Campus Cajazeiras-IFPB, the behavior of the physical properties of the selected soil was analyzed in search of the ideal granulometry. The results were compared by reference granulometric curves and analyzed according toABNT standards, thus reaching a product with considerable strength.

Conclusions: The use of available resources becomes relevant to the reality of each region, in order to assist in the development of technically viable and ecologically correct materials.

Keywords: Tetra Pak, Mortero, Sustentabilidad

INTRODUCTION

The mortar, the fundamental and extremely complex element in engineering works, has been and still is the object of study by a wide variety of researchers, from civil engineers to chemists who study the binding properties of various materials.

The technique of construction with soil, especially soil-cement with or without vegetable waste in general, despite being old, it still needs studies. The use of recyclable or natural sources materials becomes increasingly growing because there is a promising market with no occurrence of destruction of the environment, whose protection is currently under debate (SILVA, 2005).

The soil is the component that comes in greater proportion. At first any soil can be used, but it must be chosen in a way that the amount of cement required for its stabilization is as small as possible, reducing the mortar's final cost (Souza et al., 2008).

The most favorable soils for the production of mortars are those with sand content ranging between 45 and 90%, silt + clay content between 10 and 55 %, clay content less than 20% and liquidity limit less than 45%. indicates a sand-silt as a type of soil that has good resistance when compacted and becomes almost impermeable (CEPED,1999; SILVA, 2005; BUENO e VILAR, 1998),.

It is known that the advantages of mortar made with soil-cement are diverse, however, innovation is appreciable when this technology is enriched in the product matrix by the addition of new components.

This type of analysis leads us to observe the materials present in Cajazeiras county, located in the outback region of Paraíba state, we could notice some peculiarities, among them we have: Silt-sandy predominant soil, easy to obtain packages of tetra pak, large-scale use of Portland cement CP II-Z-32. Therefore, the utilization of the resources available to the reality of each region becomes relevant, so that abundant and low-cost products can help in the development of technically feasible and ecologically correct materials. After studies related to the alternative building materials, we realize there is a material widely used by the population that would be very useful in construction: Tetra Pak packaging. Which are made of packaging paper (cardboard), plastic (low density polyethylene) and aluminum. Hence they have characteristics that make them interesting for reuse because they are very harmful to the environment, and at the same time become an excellent raw material for manufacturing various products.

In order of the human beings need to live in buildings, technology has provided comfort, safety, and quality of most people's lives over the centuries. Economic viability is a major factor for all this to be appropriate for the reality of various social classes. However, the scarcity of resources provides an environment of innovation in order to develop methods and products that minimize costs and leverage the productive system. On the other hand, civil construction uses this reality to be able to flow with the help of science.

Knowing the desired properties of the raw material and considering that the tetra pak packaging has already been used as a material in civil construction, the present study aims to promoting innovation by adding crushed tetra pak in the production of mortar, since it is an abundant material in our county and easy to handle.

By glimpsing the use of the mortar in the civil construction, the mortar sustainable, made by the compaction of the soil mixture, cement and water. Considering the requirements that define the use of mortars, formulated by the addition of crushed tetra pak, its production is ecologically correct and working with this type of material is considerably cleaner, and consequently the service becomes faster, which facilitates the work delivery's time.

LITERATURE REVISION

Common mortars are porous materials produced with at leastone mineral binder (agglomerate) and one aggregate (natural orartificial sand), which are knead with water. There are records ofthe use of earth as a building material since the prehistoric period (Bruno, 2010), and of lime mortars before Christ (M. del M, 2014).

From the middle of the19th century, there was a gradual replacement of earth and limeby cement-based mortars (M. del M, 2014).

Generally, sand is the mortar component incorporated in ahigher ratio (in volume and/or weight). The binder and filler pasteshould be present in a suitable proportion to fill the voids pro- moted by the sand grains (Matias, 2014). Nowadays secondary materialsare being reused as artificial sand to increase mortars' circularity (Farinha, 2019).

Numerous binders can be applied in mortars formulation asclayish earth, gypsum, lime (air, hydraulic, natural or formulated)or cement, generating composites with diverse technical proper-ties and embodied energy (Faria, 2008).

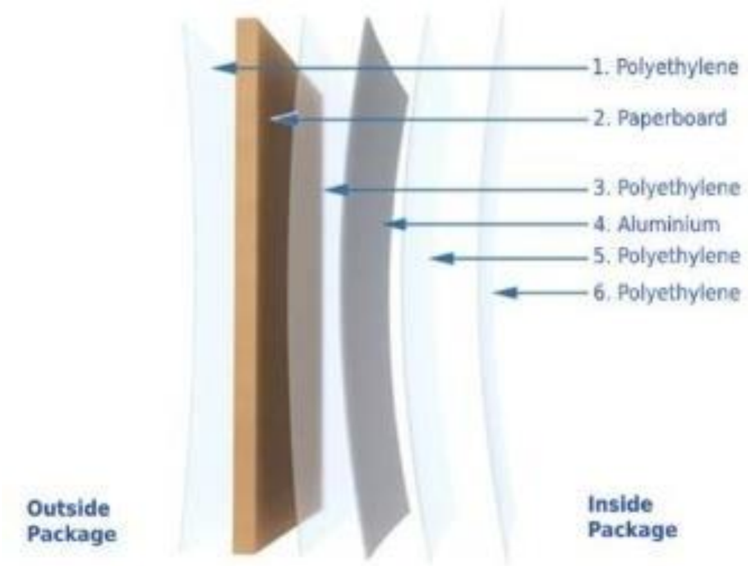
The energy involved on mortar bin-der production depends on raw material extraction, millingprocesses, thermal treatment and the transportation involved.The production of cement and limes with hydraulic propertiesrequires calcination temperatures of around 1,500°C and1,100°C, respectively. Air lime requires lower temperatures forits production [about 900°C], but still higher than the temperaturerequired to produce current gypsum [about 120–180°C], (Faria, 2018). Theclayish earth, as a mortar binder, does not require calcination,avoiding thermal energy consumption. Currently, cement is thesecond most used material worldwide (after water) and, to pro-duce 1 ton of cement, approximately 900 kg of CO_2 are releasedinto the atmosphere (Krejcirikova, 2018).

The replacement of traditional (with high environmentalimpacts) by alternative binders, which require less energy for pro-duction and transportation, would be advantageous in a technicaland social way. Simultaneously, the use of recycled aggregates inmortars instead of natural sand can also bring benefits (Matias, 2020).

The composite packaging of liquid food, commonly known as Tetra Pak®, was an idea of Erik Wallenberg, patented by Ruben Rausing and introduced into the market in 1952 (Rausing, 1969; Tetra

Pak Interna-tional, 2020a). Although this original packaging was initially made of waxed paper, today multilayer Tetra Pak® packaging is a result of laminated stiff paper (75 wt%), LDPE (20 wt%) and aluminium foil (5 wt %) (Rausing, 1969; Tetra Pak International, 2020b). A typical structure consists of 6 layers which are shown in Figure 1.

Figure 1- Tetra Pak packaging layers from outer to inner.



Source: Tetra Pak International.

According to Tetra Pak Company – part of Tetra Laval Group – in 2019 over 160 countries around the world were supplied with more than 190 billion Tetra Pak® packages while post- consumer Tetra Pak® car-tons were recycled by Tetra Pak itself with a rate of 26% (Tetra Pak International, 2020d).

The technologies generally applied to PCBCs are divided into those that reprocess them as a mixture and those that include a prior step for removing the cellulosic fibers.

In the first case, PCBCs are subjected to thermal processes (inciner-ation, pyrolysis, gasification) for energy recovery along with other municipal solid waste (MSW). Such a treatment, however, is not efficient due to the low heating value and other characteristics of paper (moisture content, high ash value) which constitutes the main material of beverage cartons. Alternatively, PCBCs are downcycled and used for the produc-tion of laminated boards or various products of different shapes by hot pressing shreds of PCBCs (Zawadiak et al., 2017).

In the second case, removal of paper is carried out through hydro-pulping: in the presence of water, cellulosic fibers are separated from plastic and aluminium layers by centrifugal forces (Selke, 2016).

Re-siduals of paper recovery, i.e. outer LDPE layer and Al-PE laminate, usually contain up to 5% paper fibers. They are mostly used in thermal processes for energy recovery due to their high heating value. A typical application is their use in cement industry, since the Al2O3 that is formed is useful for cement production (Zawadiak et al., 2017).

Govindan et al. (2016) analyzed the construction material byconsidering sustainable indicators and uses the hybrid MCDMmethod for analysis. The indicators were collected from the literature review and proposed a model to analyze the constructionmaterial.

Sustainable material selection is an essential aspect of sustain-able development. Many researches discussed the importance ofmaterial selection for new product development under a sustain-able environment (Prendeville et al., 2014; Calado et al., 2018; Maghsoodi et al., 2020). Akadiri et al. (2013)analyzed sustainablematerial selection for construction materials using the fuzzy AHPmethod. The study considered six criteria based on the triple bot-tom line approach to sustainability. A model based on the AHPapproach to analyzefiber-reinforced composites material waspresented by Ali et al. (2015). The study used an expert choicesoftware tool for analysis and found propylene as the best material.This study helps automotivefirms to enable green technology bythe sustainable selection of materials. Further,Eddy et al. (2015)presented challenges associated with sustainable material selec-tion and suggested using LCA packages for effective decision mak-ing in sustainable material selection.

MATERIALS AND METHODS

This research was developed in the Soil Analysis Laboratory at the Federal Institute of Education, Science and Technology of Paraíba (IFPB), campus of Cajazeiras city.

An analysis was made for the preliminary behavior of the physical properties of several soil types selected from specific deposits that could provide abundant raw material and located in differentiated regions, in order to obtain the ideal granulometry.

The tetra pak packages were collected at the campus' kitchen itself, at the city's sanitary landfill, at existing collection points, and through campaigns in the community. After being collected, the material was processed in a paper shredder. And it was used Portland cement CPII- Z-32.

The procedures followed the NBR (Brazilian Regulatory Norms) standards referring to the activity being developed. From the availability of all the foreseen materials, mixtures were made in the mortar with the dosages of 1:5 (cement and soil) which is the traditional mortar.

Physical characterization of soil

Samples of potential soils were collected in 3 different sources, analyzed in the laboratory, and the best option to be harvested in sufficient quantities for the following steps was defined, a layer about 50 cm was removed before collection due to the presence of organic matter, according to the guidelines of SILVA (2005), that existing soils may or may not present organic material according to their origin and formation; however, for the application in the soil-cement mixture should preferably be given to those compositions whose the organic matter is absent, in addition SUPERTOR (1989) apud SILVA (2005) says that, regardless the type, the soil must be free of organic matter such as glucose, lignin, and humic acid, since they interfere with the cement handling, by inhibiting its reaction. In the deposit, the organic matter removal was performed as shown in Figure 2.

Figure 2- Removal of organic matter.

Source: Photo by Authors.

About 1500 kg of the material was extracted, approximately 200 kg was taken to the laboratory, let to dry in the shade, and it was turned over daily for a 7 days period, in order to obtain a material with uniform humidity, avoiding later deviations; afterwards the granulometric analysis was performed following the guidelines of NBR 7181 (ABNT, 2016).

Procedures applied to the compositions

In order to add the minimum amount of cement and to maximize the use of the crushed tetra pak, in this study it was adopted a fixed amount of soil of the composition, and the variation occurred only in the values related to the addition, with regard to the amount of cement and tetra pak used. The studied doses are shown in Table 1.

The percentages of tetra pak incorporated into the mixture varied according to the traditional mix (100% cement addition). In that study, the total mass of cement was replaced in proportions of 10%, 15% and 20% for analysis purposes.

To each mixture of soil, cement, and crushed tetra pak were performed compaction tests of Normal Proctor. The compaction energies specified by the Brazilian standard NBR 7182 (ABNT, 2016) are: normal, intermediate, and modified. The compaction energy used in the tests was Proctor Normal, using the small socket and cylinder. The soil was compacted according to NBR 12023 (ABNT, 2012) in 3 equal layers, with 26 strokes per layer, which is the number of strokes required to reach the Proctor Normal value energy of 583 kJ/m3, it was determined the optimal humidity (wot) and maximum specific dry mass (dmax) for each mixture.

Table 1 – Studied doses.

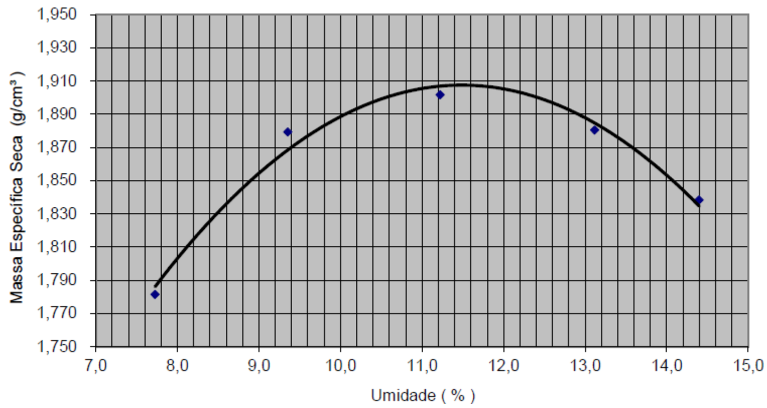
Soil	Composition	Tetra Pak (%)

1° Dosage	100% Cement	0%
2° Dosage	90% Cement	10%
3° Dosage	85% Cement	15%
4° Dosage	80% Cement	20%

Source: Developed by Authors.

In all the tests carried out, the mixtures were executed in a mortar mixed with cement, soil, and crushed tetra pak, and after attaining adequate homogeneity water was added to it. To take reference measurements regarding the amount of water to be added, a previous test of Proctor Normal compaction with soil without the mixture was carried out, the results are shown in Figure 3.

Figure 3- Compaction curve of selected soil.

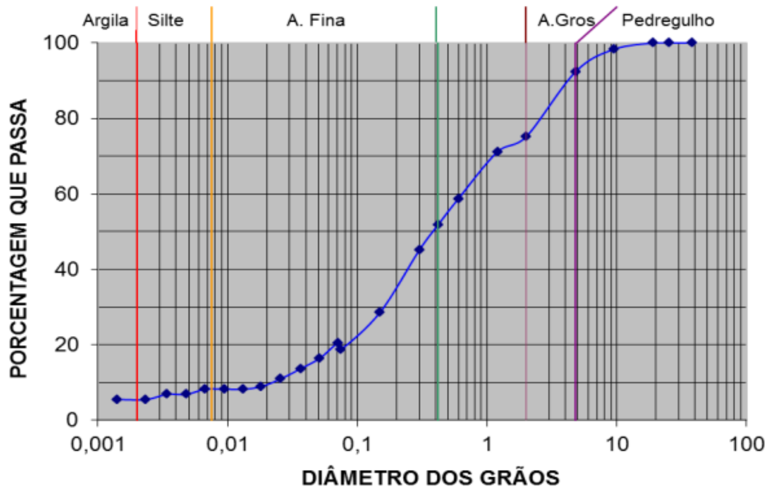


Source: Developed by Authors

RESULTS AND DISCUSSION

The initial tactile and visual analysis were compared and confirmed by laboratory tests, and the results were compared by reference gradation curves in the literature. The collected, free of organic matter soil, dried in the shade, disintegrated and analyzed according to the norms of ABNT: Physical indexes, granulometry whose result are shown in Figure 4, consistency limits that didn't present results, and compaction.

Figure 4- Soil granulometric curve.



Source: Developed by Authors.

During the molding process of the specimens it was found that the mixtures presented considerable loss of plasticity during the molding, noticeable shortly after the homogenization of all the materials of the mixture. Therefore, the preparation of the specimens did not obtain a similarity, the dosage 4 presented greater difficulty in molding, since it has a higher amount of crushed tetra pak, which induces to justify that the ideal plasticity time is directly related to the amount of crushed tetra pak added to the mixture, this particularity is due to the natural characteristic of tetra pak having high water absorption.

With the percentage of 15%, it was possible to mold aesthetically pleasing specimens. The specimens were divided in seven, fourteen, and twenty-one days and the results were obtained according to Table 2.

Table 2 - Resistance to compression in various days.

Days	Resistance (Mpa)
7	3,5
14	6,2
21	8,2

Source: Developed by Authors.

It was verified that independent of age the best results in mechanical performance were reached at dosage 2. The highest value found resistance was 8.2 MPa at 21 days.

As would be expected, during the curing period there was a significant gain of property in dosages of 1 and 2, and in particular at dosage 2. One parameter noted was the increase in apparent maximum dry bulk density at dosage 2, this particularity is justifiable since the dosage was composed of 10% of crushed tetra pak, which is a dense material that occupies the empty spaces, besides, it promoted greater lubrication of the grains, directly influencing the compaction.

Figure 5- Broken specimens.

Source: Photo by Authors.

Regarding the mixing performed in the laboratory with all the materials involved, the water levels used were determined from the homogeneity of the mixture, adding as it was observed in the process, seeking to reach the state of good workability.

Through the studies carried out, we reached the conclusion that to guarantee satisfactory resistance of the mortar it was necessary to double the amount of cement used in the production process, which generally precludes the economic benefits of the final product.

According to the values obtained by the breaking of the specimens, it is verified that the applicability can be evaluated in products that do not require great resistances, obviously evaluating new dosages that allow low consumption of cement and because aesthetically we get a well structured product with unique designer, and can thus be used with great effectiveness in civil construction.

FINAL REGARDS

The use of eco-friendly materials in the civil construction process entails the reduction of costs in several stages of the construction process, due to optimal use of raw materials, the agility that gives the design process or purchase of components, the increased productivity, and the reduction of waste and losses. The pre-made materials reduce the environmental and economic impact, since the materials are manufactured with quality control, greater durability, less waste during the production, and lower variability of characteristics such as strength, dimensions; among others. The use of recycled materials in the construction process reduces the demand for those non-renewable inputs and also the environmental pressure in the areas destined to the disposal, being the alternative for the use of conventional materials, which generate a greater impact in the environment due to the process of manufacturing.

As the tetra pak contents increase, there was a relative decrease in strength, but a beneficial aspect of the presence of raw soil-based fibrous materials is, considering that their mechanical behavior is not compromised, to obtain a product with lower thermal conductivity. , thus promoting the reduction of heat transfer and lower energy consumption to control the internal temperature of buildings.

Is important to note that other mechanical tests should be performed for practical recommendations, such as diametrical compression and absorption capacity, as well as other variations of doses.

Unfortunately, these environmentally friendly materials, as they are known, face difficulties in being widely accepted in the market, most because of their cost, however the lack

of information as for their durability in relation to commonly used materials is still very large. Which brings mutual benefits in the long term, compared to traditional building techniques.

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