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Applicability of calcined sewage sludge instead of Portland cement for coating mortars

Aplicabilidade do lodo de esgoto calcinado em substituição ao cimento Portland para argamassas de revestimento

Aplicabilidad de los lodos de depuradora calcinados como sustituto del cemento Portland en morteros de revestimiento

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Abstract
Based on the environmental assumptions that permeate the role of researchers in enabling the use of waste in consumer goods, using sewage sludge in human consumption material has become the object of worldwide study because of the potential that it carries. Aiming to fulfill the sustainable role through the creation of mechanisms that favor the ecological coexistence between environment and human beings, the use of the calcined sewage sludge as a potentiator in the properties of the material is made possible through the construction materials, behavior. Coating mortars are currently evaluated by exposing, from the replacement of the cement by the calcined material, an effective applicability with respect to its resistance to deleterious agents. It is understood that to idealize unconventional materials with the use of residues that have high degradation power to the environment, ratifies the attempt to mitigate large and irreversible environmental impacts arising from improper and poorly planned disposal.
Keywords: Calcined sewage sludge; Coating mortars; Feasibility of use.

Resumo
A partir das premissas ambientas que permeiam por entre a atuação dos pesquisadores em possibilitar o uso de resíduos em bens de consumo, utilizar o lodo de esgoto em material de consumo humano tornou-se objeto de estudo mundial pelo potencial que o mesmo carrega. Objetivando cumprir o papel sustentável mediante a criação de mecanismos que favorecem a convivência ecológica entre meio ambiente e seres humanos, viabiliza-se através dos materiais de construção, ditos como convencionais, o uso do lodo de esgoto calcinado como potencializador nas propriedades do material, melhorando significativamente o comportamento frente aos esforços mecânicos. As argamassas de revestimento são avaliadas na atualidade por exporem, a partir da substituição do cimento pelo material calcinado, uma efetiva aplicabilidade no que concerne sua resistência à agentes deletérios. Entende-se que idealizar materiais não convencionais com o uso de resíduos que possuem alto poder degradativo ao meio ambiente, ratifica-se a tentativa de mitigar grandes e irreversíveis impactos ambientais advindos do descarte impróprio e mal planejado.
Palavras-chave: Lodo de esgoto calcinado; Argamassas de revestimento; Viabilidade de uso.

Resumen
Partiendo de las premisas ambientales que permean el trabajo de los investigadores para posibilitar el aprovechamiento de los residuos en bienes de consumo, el aprovechamiento de los lodos de depuradora en material de consumo humano se ha convertido en objeto de estudio a nivel mundial por el potencial que conlleva. Con el objetivo de cumplir el rol sustentable a través de la creación de mecanismos que favorezcan la convivencia ecológica entre el

medio ambiente y el ser humano, se viabiliza a través de los materiales de construcción, dicho como convencional, el uso de lodos de depuradora calcinados como potenciador de las propiedades de los materiales, mejorando significativamente el comportamiento frente a esfuerzos mecánicos. Los morteros de revestimiento se evalúan actualmente por presentar, a partir de la sustitución del cemento por material calcinado, una efectiva aplicabilidad en cuanto a su resistencia a los agentes deletéreos. Se entiende que idealizar materiales no convencionales con el uso de residuos que tienen un alto poder degradante para el medio ambiente, ratifica el intento de mitigar los grandes e irreversibles impactos ambientales derivados de la disposición inadecuada y mal planificada.
Palabras clave: Lodos de depuradora calcinados; Morteros de revestimiento; Viabilidad de uso.

1. Introduction

In Brazil, already in the second half of the 20th century, factors such as the growth of cities and urban agglomerations with the increase in immigration flows, worsened sanitation problems, with epidemics reproducing periodically (Passeto, 2006). This rapid inversion has turned the lack of sanitation into one of the main Brazilian environmental and public health problems.

The Brazilian Ministry of the Environment estimates that around 10% of urban sewage is treated in Sewage Treatment Plants (STPs). This treatment results in the production of a sludge rich in organic matter and nutrients.

According to Waldemar (1992), in urban areas, sanitary sludge is generated daily in large volume, depending directly on the percentage of sewage that is treated. It is estimated that they can reach an amount in the order of 1000g/inhabitant/day, of partially dry material, which can contain between 70 and 90% of water in its composition. When fully dehydrated, it becomes, on average, 150g/inhabitant/day. When fully dehydrated sludge is calcined, approximately 33% of the dry material is obtained from ash (Geyer, 2001).

The most used sludge disposal, until the 60s, took place in sanitary landfills, however, with the growth of cities and consequent increase in the amount of waste, this alternative became ineffective from an environmental point of view.

In large cities, environmental legislation increasingly restricts the disposal of sludge in landfills, the major problem being the scarcity of suitable locations and the high costs for such disposal.

According to John (2017), civil construction is the sector responsible for the consumption of the largest volume of natural resources, in estimates exceeding 50% of the resources extracted on the planet, in addition to its products being large energy consumers, and for these reasons, it is fundamental importance is the development of alternative materials that meet this activity. Furthermore, according to Cunha Oliveira et al., (2021), the strands of studies for unconventional materials nowadays emerge from the need to seek to cover, through laboratory studies, the creation of mechanisms that favor the realization of such a claim.

The high energy consumption of industrialized materials used in civil construction should stimulate studies and actions to plan the reuse of waste in its processes. According to Lerepio (2004), in China, a country with a considerable territorial extension and with high rates of population density, the population considers waste to be a responsibility of the citizen, that is, of the generator. With the support of the population's conscience allied to an ancient culture, the country is easy to implement actions to control and reuse waste.

Waste recycling is a topic that has played a prominent role in research developed in recent years. According to Cunha Oliveira et al., (2021a), the design of studies that seek to incorporate the eco-efficient potential into conventional materials is becoming increasingly present due to the considerable increase in the consumption of non-renewable raw materials. According to Geyer (2001), among the urban waste, one of the most problematic is the one generated in the domestic sewage treatment processes, the so-called Sludge from Sanitary Sewage Treatment Stations, Sanitary Sludge or Organic Sludge.

The final disposal of sewage sludge residue has been the subject of several studies, since it has become a serious environmental problem, because, on the one hand, basic sanitation and public health are promoted through sewage treatment,

on the other hand. generated in the processes undesirable compounds due to the high pollutant load they carry.

A problem is then established: where and how to dispose of sanitary sludge from large urban centers in a safe way? It is therefore necessary to seek the development of alternatives that efficiently replace the simple disposal of these wastes. According to Cunha Oliveira et al., (2021b), in view of the technological advances that the civil construction sector is immersed in, measures that can improve and bring benefits to the technical applications developed in each specified case are being increasingly palatable, with plausible solutions based on the needs arising in practice.

The best way to reduce the residue is its reuse in other activities, such as its use in the construction industry, that is, partially replacing Portland cement, which is one of the materials used in construction that most causes the emission of CO_2. The cement production process has been pointed out as a generator of both environmental and social impacts, therefore reducing its use would generate the minimization of environmental impacts and implementing measures that aim to reduce this high consumption configured today happens from the use of these additions. on conventional materials such as coating mortars. According to Cunha Oliveira et al., (2021), this measure would directly impact the reduction of the amounts of Portland cement in cement-based compositions, which contributes to the reduction of the carbon footprint and sustainable development, due to the pozzolanic behavior presented by the sewage sludge after its calcination.

2. Methodology

As a methodology, a bibliographic search was carried out in the main scientific databases (ScienceDirect, Google Scholar, and Scielo), about the types of ecological concrete developed in Brazil and in the world, and ways of applying this unconventional technology. Thus, the ideas advocated at the beginning of this study will be explained according to the types of concretes that have practical application potential, according to each study location, as well as before the respective solid residues that are adopted as renewable inputs in their compositions (Cunha Oliveira, 2020).

3. Theory

The most used sludge disposal, until the 60s, took place in sanitary landfills and most Brazilian cities threw their sewage directly into water collections, polluting them and resulting in chaotic situations such as, for example, the Tietê River in Sao Paulo. To alleviate the problem, policies were created to encourage basic sanitation and policies to encourage the installation of sewage treatment stations in cities.

There are three main reasons that motivate countries to recycle their industrial waste; first, the depletion of reserves of reliable raw materials; the growing volume of solid waste, which jeopardizes public health and degrades natural resources and, finally, the need to compensate for the imbalance caused by high oil prices (Menezes et al., 2002).

Several scholars from developing countries analyze the insertion of waste in civil construction in their studies. Tay (1987) carried out studies and research aiming at the reuse of sewage sludge in the civil construction industry, aiming at the insertion of the residue to produce ceramic blocks. Civil construction is an industry that has considerable potential for the incorporation of waste in its construction stages with the possibility of reducing costs and reducing environmental damage and in coating mortars such a practice also needs to be evaluated and researched.

The coating mortar has different types, according to the function they present. The roughcast is the initial layer to prepare the base, in order to improve the adhesion of the other layers. The plaster is executed above the roughcast and its purpose is to smooth the surface to receive the plaster (finish also in mortar to receive the painting) or for the adhesive mortar when the finish is in ceramic pieces.

According to Recena (2012), mortars should be considered as an element of a system and not in isolation as a

material. Also, according to the author, the coating mortars must present characteristics that allow a good finish, absorption of the natural deformations that the structure is subject, waterproofing of the substrate, among others. The study on the pozzolanic activity index of mortars made using calcined sewage sludge partially replacing cement is of great importance to assess whether the unconventional material has characteristics similar to those of the binder.

According to Mehta and Monteiro (2008), one of the main primary constituents of Portland cement are calcium silicate sources. The discovery of pozzolanic activity in a given residue can direct its use in the manufacture of cements, where they are used to guarantee the binding properties of the material. The study of the alkali-aggregate reaction in mortars using calcined sewage sludge is necessary to evaluate the durability of the mortar executed using the unconventional material, in this case the calcined sewage sludge that will be partially replaced by cement.

According to Couto (2008), there are three main conditions for the alkali-aggregate reactions to occur: the presence of an aggregate with reactive minerals, a high concentration of alkali hydroxides (NaOH, KOH) in the pores of the concrete and, finally, the presence of sufficient moisture to expand the gel and form cracks in the concrete, in which the calcined sewage sludge shows potential in reducing the expansive process by the amorphous structure produced through the calcination process and by the pozzolanicity obtained when acting as a substitute for Portland cement (Oliveira, 2017).

In addition to the practice that civil construction addresses about the absorption of waste in cementitious materials, Geraldo (2016) proposed a model for creating a binder with properties similar to Portland cement, through alkaline activation, consisting of sludge from Water Treatment Station and rice husk ash. The author replaced the metakaolin by sludge and rice husk ash, separately, during the process of activating binder from sodium hydroxide (NaOH) with curing at room temperature. It was possible to obtain, at 28 days of hydration, a mortar with a strength of 25 MPa when the metakaolin was replaced by 15% by sludge, a value within acceptable parameters in civil construction when mortars are involved. Another relevant parameter for the study was the fact that the component denotes low efflorescence, a pathology associated with the leaching of soluble compounds to the surface of the material, physically deteriorating it and causing a partial loss of its performance, and the sludge applied in the study brought a significant reduction in this aspect evaluated.

Viana (2013), sought to apply the pyrolysis method to extract the adsorbent potential that sewage sludge denotes when subjected to high temperatures. Pyrolysis consists of submitting the dry material, macerated, and sieved in ABNT #200 mesh, to a degrading thermal process, better known as calcination, at 500°C for 5 different isotherms. The times of 30 and 60 minutes showed satisfactorily superior results compared to activated charcoal for the removal of pollutants, such as phenol and tartrazine, from aqueous media.

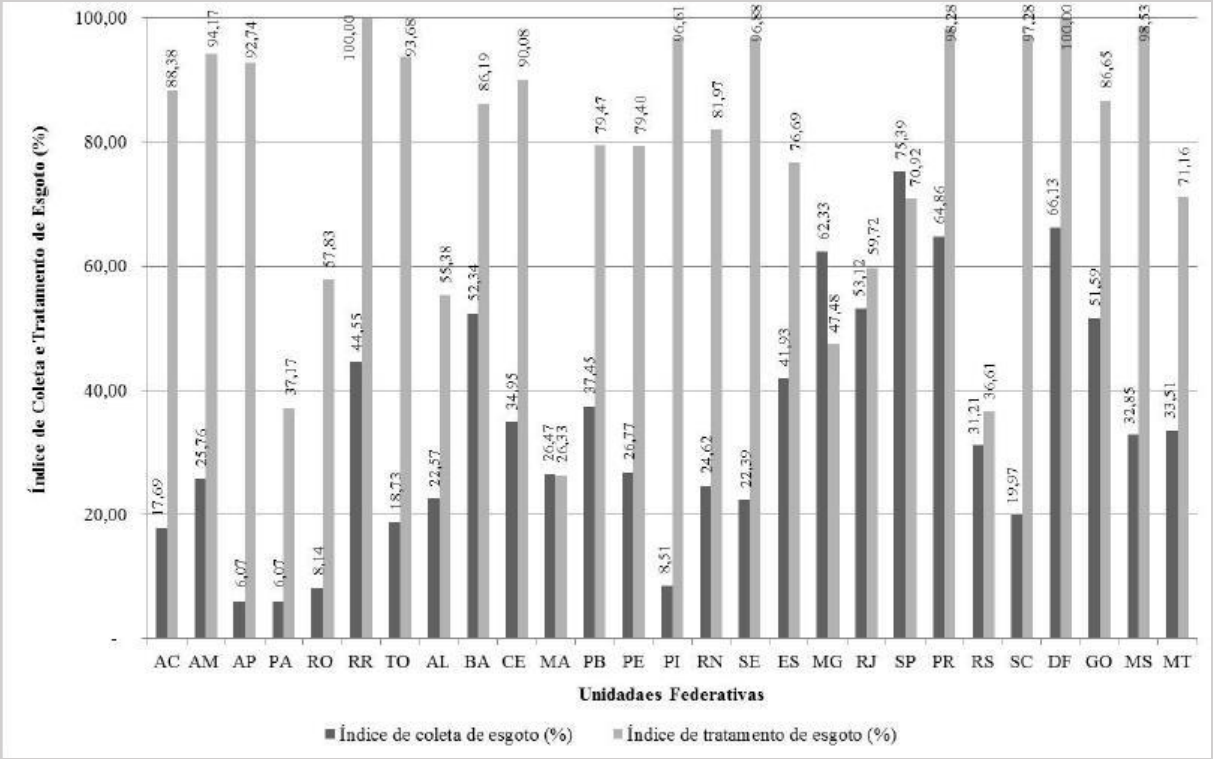
Thus, it is observed that using sewage sludge, in natura or calcined, one can obtain several benefits in the environmental and technological spheres. The products that are created to reduce environmental impacts are characterized by the viability proven through laboratory tests, which inorganically characterize the properties of the material created and of the residue in its application form.

4. Discussion

The environmental problems that the sludge can produce due to poor planning are linked to the search for circumventing the environmental legislation in force on the subject, as well as making a bad use of them with incomplete procedures in the disposal, not guaranteeing the smallest influence of the residue in the imbalance of the fauna and flora in contact. According to Cunha Oliveira et al., (2021), sludge production can be considered as a sanitation problem, due to the population growth that increases its production, implying an increasing demand for area for its environmentally adequate final disposal.

Using the sludge produced is a task that permeates aspects of technical and economic feasibility, in the same way that the studies produced try to cover these two spheres in balance. Castro et al., (2015), show that the scenario of sewage collection in Brazil, and its respective treatment, is totally asymmetric (Figure 1).

Figure 1 – Sewage collection and treatment rates in each federative unit.



Source: Castro et al., (2015).

Andreoli et al. (1998), explain that "the quantity and quality of the sludge produced by an STP depends on the flow of treated sewage, the characteristics of the sewage, the type of treatment and the operation of the STP", and it should be considered that for each region of the country, there are several products generated through the chosen treatment process, which will vary in each reality.

Pedroza et al. (2010) state that, per year, the production of sludge ranges from 150 to 220 thousand tons of dry material and considering that only 30% of the population has its sewage properly collected and treated, it is assumed that in 100% of collection, the annual volume produced would exceed the mark of 400 thousand tons.

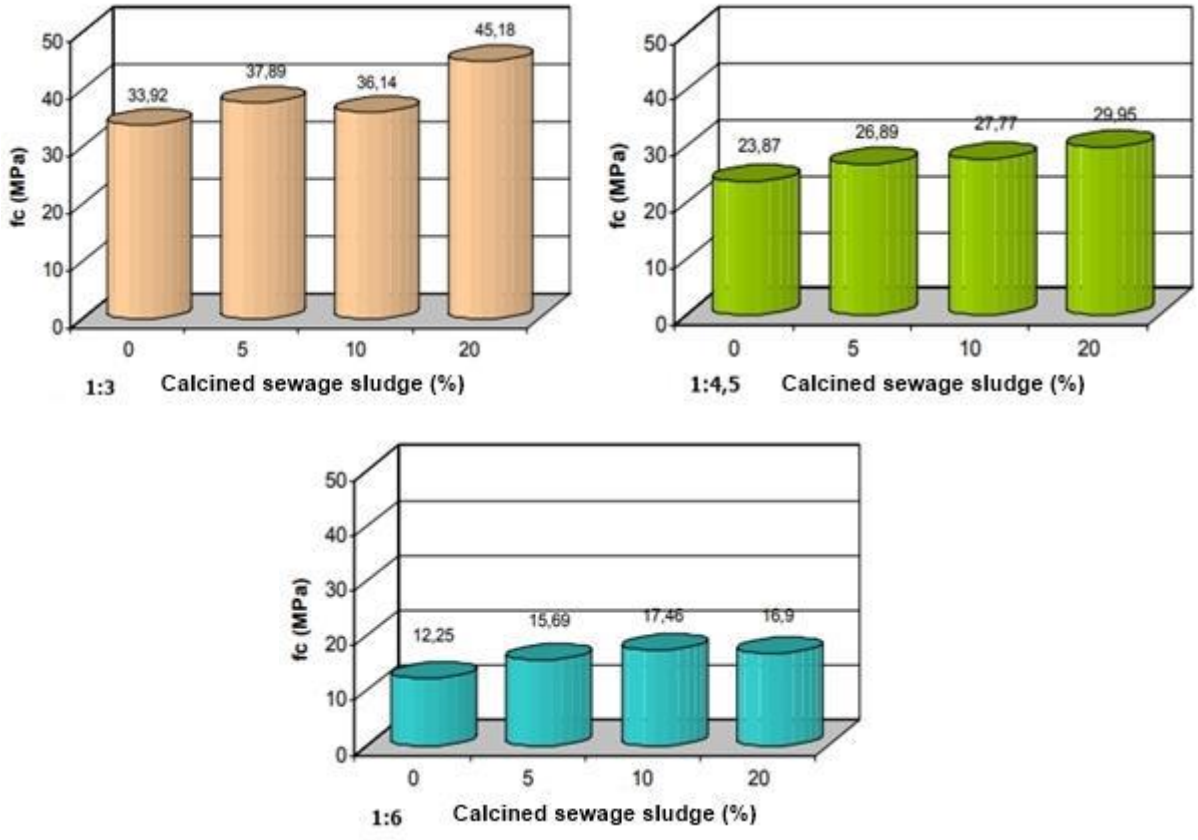
This large volume of sludge generating demand for high operating costs of the sewage treatment plant itself in the designation of disposal, and the consequent applicability of this by-product in construction materials is characterized as viable from the calcination process, eliminating organic matter and promoting chemical reactions very important in obtaining crystalline phases that corroborate pozzolanic activity to the calcined material when in contact with calcium hydroxide, a hydration product of Portland cement.

Cunha Oliveira et al., (2020), evaluated the use of calcined SSA at 600°C and 700°C, incorporated in coating mortar in percentages of 10%, 20% and 30%, and evaluating the mixtures in terms of flexural strength, and adhesion to the masonry substrate. The authors concluded that both temperatures contribute to the SSA becoming reactive enough to be pozzolanic, a factor directly reflected in the increase in the flexural strengths and the adhesion of mortars, with emphasis on 700°C, which

produces more dehydroxylated amorphous structure, that is, more reactive, so the resistance values are higher for the temperature of 700°C.

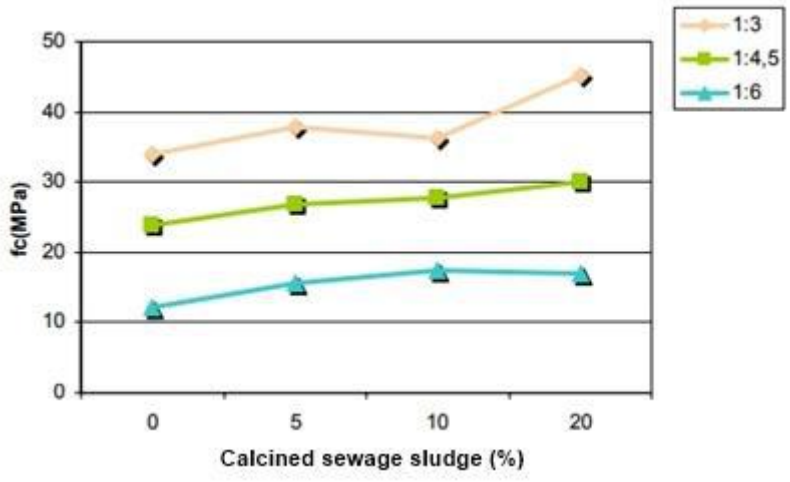
Lessa (2005), evaluated some properties of mortars with the insertion of calcined sewage sludge at 550°C, for 3 different traits (1:3, 1:4.5 and 1:6), replacing the cement in fixed percentages of 5, 10 and 20% to measure the compressive strengths after 28 days of curing the mortars (Figure 2). The author observed that for all the mixes, all the percentages of sludge added favored the respective increase in strength compared to the reference mix (Figure 3), making it possible to effectively apply the ash from the calcination process instead of cement, also generating agent of significant deposition of CO_2 in the atmosphere.

Figure 2 – Axial compression strengths of mortars with sewage sludge ash.



Source: Lessa (2005).

Figure 3 – Behavior of each formulation according to the amount of ash added.



Source: Lessa (2005).

Another alternative studied for a better destination of the sludge is using it as raw material in the manufacture of cement. Chen et al., (2010), state that the replacement of limestone in percentages up to 7% provides higher strengths to the material. From 4 to 10% replacement, the cement obtained higher strengths at 3 and 7 days of age compared to the base cement composition. For the age of 28 days, the percentage of 7% is the most favorable to use, reaching strengths around 73 MPa.

Lin et al., (2012) observed the behavior of using dry sewage sludge as an additive to cement properties during the clinker burning process. Additions of 5 and 15% of dry sludge were added to the raw flour, to then be mixed and calcined at 1450°C for 2 hours, where it could be seen that the clinker components of ecological cement with sludge were equivalent to that of simple cement. The results regarding the flexural and compression strength of the hardened eco-cement pastes showed that from 0.5 to 15% of sludge use there was a balance in the results, not exceeding 2% for bending, and 11% for compression against the trace base.

Banfill e Frias (2007) consider calcined sludge as recycled metakaolin, as it produces similar properties when calcined at 700°C and becomes a supplementary cementitious material when used in mortars. In the same way that metakaolin can be replaced by sludge ash, it contributes to a significant reduction in the production of this mineral addition from kaolinite natural resources, associated with reduced environmental load with the destination of the large volume of sludge generated daily in the STPs.

5. Conclusions

Faced with numerous environmental problems experienced, it is necessary for scientists and researchers to promote the development of the use of materials and components that are easily reincorporated by nature and that reduce pollution. The use of waste in construction processes is a method of inserting the practice of sustainability that provides environmental, economic and social viability, but specifically in construction sites, there are many obstacles in applying technologies that promote any form of execution in civil construction that is differentiated from traditional building systems.

Applying calcined sewage sludge in materials with conventional methodologies that significantly fills several negative factors attributed to incorrect disposal and attitudes that neglect the environmental damage caused, and it is concluded that there are several ways to assign an increasingly effective destination, in line with the environmental premises and with the quality and performance standards of construction materials, attributing similar or superior potential to them when calcined or in natura sewage sludge is added to the composition.

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