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# GREEN BRICK AN ALTERNATIVE FOR THE CONSTRUCTION INDUSTRY

## Keywords:

Construction Industry, Green-Brick,
Waste-Recycling

## Abstract:

The sustainable development in the building sector, needs to integrate environmentally sustainable solutions. In the herein research work a new sustainable green-brick, using celluslosis waste, is introduced aiming at the sustainable development in the construction industry. The use of waste contributes to the reduction of landfills with the consequent availability of suitable areas for reafforestation and the production of low-cost raw materials with energy consumption reduction, and diminishing the carbon footprint The purpose was to characterize a cement brick composed of cement, sand, dregs (in two different proportions), and water.

In the current world's food crisis, the need to preserve healthy and fertile soils is one of the needs of today's societies and a key point for the EU Green Deal in what is the Road map for the sustainability of the European Union. Promoting resource use efficiency through the adoption of a circular and clean economy in climate change scenarios, reversing biodiversity losses, and controlling pollution, in soils, water, and the atmosphere, are critical for the future of our planet. The present project is at Technologic Readiness level (TRL) 7 and Business Readiness Level (BRL) 4. It is anticipated that TRL 9 will be achieved within one year – and within two years to BRL 7.

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# INTRODUCTION

The key objective of this survey is the development of a new ecologic brick, using cellulosis waste. Therefore, reducing the consumption of raw materials and, at the same time, saving energy and reducing the $CO_2$ impact. The integration of environmentally sustainable solutions is important for sustainable development in the construction sector. In particular, the use of industrial waste materials such as aggregate sweeps or binding agents in a mortar and concrete mixtures. In this context, the pulp and paper industry, which generates large amounts of waste known as dregs, makes it possible, for example, to, on one hand, a free solution for waste produced by the pulp and paper industry and, on the other hand, the solution for the construction industry of waste. In this way, promoting the production of an eco-product at a low cost also leads to a reduction in carbon dioxide ($CO_2$) emissions and its production into a concept of circular economy and sustainability. This solution addresses sustainable development in the construction industry where the incorporation of environmentally sustainable solutions is mandatory. Specifically, the use of industrial residues to replace aggregates or binders in a mortar and concrete mixtures. In this context, the pulp and paper industry, which generates large amounts of waste known as dregs, allows, either a free solution for the waste produced by the pulp and paper industry as an ecological solution for the construction industry. Promoting the production of an eco-friendly product at a low cost, while reducing carbon dioxide ($CO_2$) emissions, is framed by a circular economy and sustainability concept.

There are several solutions in the market for making green bricks. In all these cases, the mixture consists of a proportion of sand, cement, and water. With the solution presented, the innovation comes from replacing the sand with an aggregate of cellulosic origin, promoting the reduction of raw material consumption by about 30%, (natural aggregate), and with a saving of €0.011/unit, which means a global production cost reduction about 10%. The use of waste helps to reduce landfills with the consequent availability of suitable areas for reforestation and the production of raw materials. For instance, the number of eucalyptus trees which can be planted in one hectare varies between 1100 and 1700. On average, one eucalyptus may produce about fifteen reams of paper (A4 to 75g) (Wu et al 2022, Aneke and Shabangu, 2021).

Today, the world's food crisis involves the preservation of healthy and fertile soils as a key point in nowadays societies. Promoting the EU Green Deal as expressed in the Roadmap for Sustainability manifesto. The adoption of a circular and clean economy in climate change scenarios allows for reversing biodiversity losses, and controlling pollution, in soils, water, and the atmosphere, which are critical for the future of our planet.

# MATERIAL AND METHODS

In the production of pulp, the wood is disintegrated into cellulose and the pulp production process is relatively simple, but at certain stages waste has generated that call into question the final quality of the product if they remain present in the next processes, such as the case of waste called dregs. According to Pinto (Pinto, 2005), the pulp production cycle starts when the wood is cooked. The fibers are separated and a thick black liquid is produced, called black liqueur. Then it goes through two stages: recovery and bleaching. In the first step, the black liquor is burned in a boiler for the recovery of chemical cooking reagents (giving rise to the dregs); in the second step, the wood fibers that came out of the cooking are bleached. After, bleached cellulose is shipped for drying and packaging at its final destination. The dregs, the object of this study, are, therefore, residues generated in the chemical recovery of black liquor, presenting in its constitution impurities such as incomplete combustion particles and solid salts whose ions are oxides, carbonates, and sulphides of elements (such as iron, silica, calcium, aluminum, and magnesium) that enter the manufacturing process with the raw material (wood), water and chemicals. Residues are harmful to the effectiveness of the chemical recovery process, so it is necessary to separate the black liquor by sedimentation in a green liquor clarifier. These residues, once removed from the clarification tank of the green liquor, are dense thickened and filtered, and ultimately deposited in landfills.

## Experimental methodology

The trial design is based on the following components: Portland cement CEM II/A-L 42.5R and sand (FS). The type and size of the aggregates used in the compositions are given in Table 1.

Table 1
Type and size of aggregate.

| Aggregate type | | Aggregate size |
|---|---|---|
| **Fine** | sand (FS) | < 4mm |

The trial was divided into two stages. In the first stage, three mortar compositions were analyzed according to the quantity of added residues (dregs).

Figure 2
Pulp industry waste - Dregs

Namely, in the first composition, referred to as plain mortar (RM), no residues were added. In the second and third compositions, residues were incorporated (Figure 2) replacing soil in the corresponding proportions of 15% (MD1) and 30% (MD2).

The purpose of the second phase was to characterize a cement brick composed of cement, sand, dregs (in two different proportions), and water (Figure 3).

Figure 3
Soil-cement speciments

According to current legislation, dregs correspond to a solid by-product that contains a small amount of toxic heavy metals and their classification in the European Waste List (LER) corresponds to code 03 03 02 - Green lye sludge (from the recovery of cooking), being taken from the recovery of chemical products, from the clarification of green liquor, in the processing of cellulose separation (Commission Regulation, 2014).

The analysis of the total elemental composition showed that the residue consists mostly of Ca, Na and Mg, and has a potential for bioavailability and mobility of nutrients capable of improving agricultural soils. The leaching behavior of heavy metals and polycyclic aromatic hydrocarbons revealed that the levels released are very low, confirming that the residue is a non-hazardous type(Matias, 2012).

The dregs' granulometric distribution revealed a material consisting mostly of particles size of less than 0.063 mm, which is considered a filler and falls within the silt and clay (fine) classes (Figure 4).

Figure 4
Dregs - particles after sieving separation

The decision was made to replace the sand with residue due to its size.

The mortar compositions are given in Table 2.

Table 2
Mortar compositions

| | CEM [$m^3$] | FS [$m^3$] | Dregs [$m^3$] |
|---|---|---|---|
| **RM** | 1 | 3 | - |
| **MD1** | 1 | 2.55 | 0.45 |
| **MD2** | 1 | 2.10 | 0.90 |

Table 3 shows the compressive strength and strength class of mortars tested under EN 206-1 (EN 206-1, 2007). The speciments were cured in the laboratory where the atmospheric conditions were of around 20ºC temperature and 60% of relative humidity. The samples were tested over a period of at least three months.

Table 3
Compression strength of tested mortars

| Mortar type | $f_{cm}$ (MPa) |
|---|---|
| RM | 22.50 |
| MD1 | 7.80 |
| MD2 | 2.60 |

The mortar compression strength assessment was carried out on 150mm cubic test pieces.

The experimental design of the compression tests consisted of a universal tensile/compression machine of 600kN capacity.

This was accomplished by breaking the test pieces and recording the final load to which they were resistant. The compressive strength value was calculated by the quotient between the maximum force reached in the test and the cross-section area of the specimen in contact with the plates of the press. The test procedure was adopted under NP EN 12390-3 (NP EN 12390-3, 2011).

The results obtained at 28 days show that the substitution of sand by dregs consists of a considerable loss of compressive strength of the mortar. This makes dregs, considering the proportion used, an undesirable material for cement replacement. A possible explanation is dregs' fine granulometry (less than 0.063 mm), corresponding to the categories of silt and clay. However, the visual analysis allows verification that the specimens have the characteristics of a homogeneous material, without voids, and the soil-cement bricks, after 28 days of curing, showed a simple compressive strength similar to that of the ceramic bricks, with an average value of 1.8 MPa (Figure 5).

It should be noted that the material used comes from industrial waste and a further study on the effects of dregs on public health must be conducted, as in this study, only its usefulness in the construction industry was verified.


Figure 5

Stages of the laboratory methodology and experimental prototype wall

# RESULTS AND DISCUSSION

There are many solutions on the market for the production of eco-friendly bricks. In all these cases, the mixture consists of a proportion of sand, cement, and water. In the solution presented, innovation comes from replacing the soil with an aggregate of cellulosic origin, promoting the reduction of the consumption of raw material (natural sand), and the use of a residue (contributing to the reduction of landfills).

The results obtained regarding the mechanical behavior of the soil-cement mixtures are shown in figure 6, obtained at 7 and 28 days of age, for mixtures with different dreg proportions. The test objective was the determination of the stress failure under compression, for each soil-concrete speciments, where the maximum load supported was recorded and the soil-cement compressive strength was calculated.

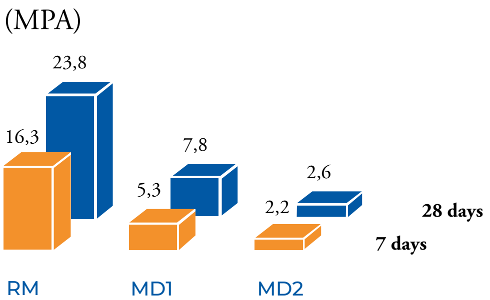


Figure 6

Average results of the compression testing

The analysis of figure 6 shows that the mixtures in which there is a replacement of natural aggregate by dregs, had a very significant loss of compressive strength, compared to the reference mixture. Therefore, it is possible to conclude that the replacement of a proportion of sand by dregs has a great impact on the final results. The test of soil-cement speciments at 28 days, with a soil replacement of 15% dregs, showed a compressive strength value equivalent to 33% of the reference mortar speciments compressive resistance and only 11% when considering a soil replacement of 30% dregs. However, it is interesting to verify that both percentages are still above the referred values for admissible compressive strength at 28 days of age values, namely, equal to or greater than 2.0 MPa (NBR 10834, 1993). The resulting bricks have good mechanical features for compartmentalization uses, even if not for structural purposes. Furthermore, considering water absorption it is possible to verify that the samples tested to show results far from the 20% water absorption admissible limit (figure 7), following the Brazilians and Portuguese at 28 days of age (NBR 10834, 1993) (E 394. 1993). Thus, it is possible to conclude that the soil-cement brick with an addition of 15% dregs, complies with the Brazilian standard NBR 10834/1993, on the conditions required for common soil-cement blocks, intended for the execution of masonry and without structural function.

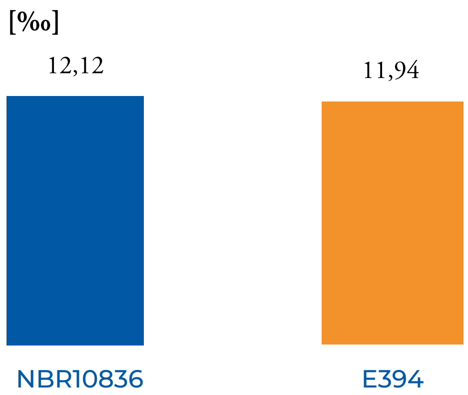


Figure 7
Water absorption outcomes

Compared to traditional brick (ceramic brick), the absence of $CO_2$ emissions decreases the carbon footprint and contributes significantly to the reduction of soil consumption. It should be stressed that soils require healthy characteristics as contaminated soils cannot be used. In the current crisis, the need to preserve healthy and fertile soils is one of the needs of nowadays societies and a key point for the EU green deal in what is the road map for the sustainability of the European Union aiming at solutions/opportunities promoting resource efficiency through the adoption of a circular and clean economy considering climate change scenarios and reversing biodiversity losses, as well as promoting pollution control in soils, water, and atmosphere.

## Technology and Business Readiness Assessment

This business project is at Technology Readiness Level (TRL) 7: demonstration of a functional prototype representative of the technology in an environment (ISO 16290:2013), and Business Readiness Level (BRL) 4 - presentation of the first version of the business model with the first feasibility projections economic growth and market potential (Ramsden R. and Chowdhury M., 2019). It is intended in a one-year horizon to achieve TRL 9: a technology implemented industrially effectively, and within a two-year horizon of achieving BRL 7: a product adapted to the market with of attractive profit cost binary.

The strategy adopted to reach BRL 7 requires significant advertising/marketing actions. Therefore, a specialist for the development of market research actions and prospective customers is needed for dedicated awareness/marketing. The founding team will provide a follow-up and clarification service within a customer support policy throughout the project execution period, individually and continuously.

## Benefits and Risks

The benefits can be recognized as follows: 1. Performing time-saving. Working with this type of material is much simpler than using traditional masonry. 2. The construction becomes more economic since it is a monolayer. 3. It does not require finishing touches because it is meant to look rustic/ natural. 4. Lower CO2 emissions. 5. Reusability of industrial waste. 6. Reduced usage of natural raw materials. Most important risks: 1. Technological risk - shortage of material, namely those of cellulosic origin - dregs. As a mitigation measure, studies are being conducted on the use of other environmentally sustainable tailings as an alternative.

2. Production/distribution risk - production/distribution delays. As a mitigation measure, it is designed to outsource alternative enterprises for the production/distribution of the product. 3. Commercial Risk - not meeting expected sales level. As a mitigation measure, the intent is to increase outreach and marketing measures, given the possibility of hiring an additional member for this working group. This product is part of the EU's Green Deal - Roadmap for Sustainable Economies and is in line with what will be the future European directives for economic and technological development. The sociological and cultural point of view will require the enterprises of the future a continuous work of clarification and individual accompaniment of the client.

## Market perspective

Sales activity will be driven by the relationship with the customer and the overall shopping experience offering advantages such as agility in delivery times and giving consumers the freedom to give their opinion about the purchased product. Thus, promoting an elegant and exclusive service, both in the product and in the services. For the launch of the brand "Ecological brick dregs-cement," the question to be answered is "What makes this product so important?". A structured communication strategy will be defined using social networks, Hot Sites, events, and an aggressive both pre-sales and after-sales strategy opening space for the clarification of customers' doubts and requests.

From a holistic conceptual perspective, two lines need to be taken into account: 1. Market - establish a clientele by providing periodic market research to ensure a proper perception of competition and market changes. 2. Company - after identifying the costs involved in the production and establishing the profit margin, consider the product in a flexible manner (for example integration of other types of waste) and the maintenance of an aggressive marketing policy.

The entire production and distribution processes will be outsourced and supervised by the founding team. The activity chain can be defined based on what is expected in Porter's Value Chain (Koc and Bozdag, 2017). Namely: 1. Main activities - logistics and incoming operations linked to contracted companies. The company will assume responsibility for logistics, marketing, sales, and service (customer support). 2. Support activities - the infrastructure of production and distribution under the responsibility of the outsourced companies;

With the introduction of the long-awaited "Fit for 55" legislative package, the European Commission intends to guarantee compliance with the reduction of greenhouse gas emissions by 55% by 2030, compared to 1990 levels. In practice, this means that every industry will have to pay to pollute. The promotion of an innovative solution, with a reduction in $CO_2$ emissions, is part of the answer to what is the price of carbon, allowing important future synergies with other sectors of civil construction that intend to reduce their ecological footprint.

The company's growth potential is worth considering as it adds an ecological solution for waste that will not incorporate the volume of industrial landfills. It is planned to broaden the staff in critical areas such as sustainable construction, natural raw materials, the environment, and environmental legislation/legislation.

## CONCLUSIONS AND FURTHER RESEARCH

The main purpose of this survey was to research a new ecological brick using celluloses industry waste and its incorporation into the design of soil-cement bricks.

Initially, experimental methods were used to characterize a dreg sample. Two analyses were performed, one for geometric properties and the other for physical properties. The dregs residue is undoubtedly a dense material, as it has a density equivalent to a quartz mineral, demonstrating the impossibility of significantly reducing the volume in the landfill. Its granulometric distribution shows a material consisting mostly of particles smaller than 0.063mm, which is considered as a filler and fits in the Silt and Clay (fine) granulometric classes. Therefore, consisting of very fine material. The key objective of this research was to analyze the results of the possible integration of dregs in civil construction materials, through the incorporation of dregs in bricks manufactured by a soil-cement mixture. The experimental work and test methods consisted in characterizing the compressive strength of a reference sample without the addition of dregs and two samples with the addition of 15% and 30% of dregs. The analysis of the results obtained showed that the mixtures in which there is a replacement of the natural aggregate by the dregs had a very significant loss of compressive strength when compared to the reference mixture. However, since in Portugal there is still no specific regulation referring to soil-cement bricks, the Brazilian standard NBR 10834/1993 was followed, which sets the conditions required for common soil-cement bricks, intended for the execution of masonry without structural function. The results obtained for compression strength and water absorption are within the 28-day age limits of the Brazilian standard. Thus, the incorporation of cellulose residues as a substitute for the natural aggregate in soil-cement bricks can become interesting From an environmental point of view, releasing landfill for future forestation, and at the same time reducing the use of natural soil resources, implies diminishing raw materials consumption. It is also considered that the soil-cement brick proves to be ecological, being a product that fits within the sustainable development plan, which encourages the use of new techniques and alternatives to replace products and processes that harm the environment.

In future work, it is considered 1. characterizing bricks with different geometries; 2. Manufacture bricks with the addition of dregs, with the same binding agent, but with other natural aggregates; 3. Manufacture of bricks with dregs added, with the same natural aggregate, but with smaller quantities of binder (cement); 4. legislation for cement bricks proposal for the EU.

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