v. 4, n. 17, 2024

Journal of
Engineering
Research

RECYCLED HDPE (HIGH DENSITY POLYETHYLENE) PLASTIC TILE AN INITIAL PROTOTYPE

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Abstract: Brazil is currently undergoing several developments in the area of technology and sustainability, as through Civil Engineering, it has been promoting sustainable means using existing raw materials such as plastic and the unrestrained consumption of oil and its derivatives. Plastic is a material found in abundance in our society as it has several uses. Furthermore, as garbage, it is also discarded improperly, thus causing an overload on the environment. Along with existing developments, new ways of reusing waste are studied and applied through the reuse of plastic in various construction sectors, thus helping to reduce the impact on the environment and the economy. Therefore, using plastic recycling, it is possible to transform waste that would otherwise be discarded incorrectly in nature into sustainable tiles, thus reducing the impacts that these plastics could cause on our ecosystem. This study will seek to produce a tile made from recycled HDPE plastic as a raw material, which achieves similar or superior results to the tiles we use in our daily lives, following current standards.
Keywords: Sustainability, Plastic, Environment, Recycling, Tile.

INTRODUCTION

Contamination caused by plastic is a major environmental problem that plagues not only poor or developing countries but also the richest on the planet, mainly due to irregular disposal that affects nature in an often-irreversible way. Materials in conventional use, widely spread, and which are important in civil construction works, such as sand, for example, come from dredging rivers or crushing stones, and which, when exploited, harm the environment, that is, when there is exploration of rock deposits for the production of aggregates.

The ever-increasing need for new housing significantly increases the consumption of these materials and consequently the exploitation of these resources. This need occurs due to the large housing deficit caused mainly in our country by poor income distribution, lack of job creation, lack of social projects that effectively encourage the sustainable construction of low-cost housing and other factors such as natural disasters, which contribute so much to this housing gap, especially in large cities. However, this need to remove raw materials from natural and exhaustible sources can be minimized with the creation of specific technologies for civil construction, which produce effective results both in the cost of materials and in the environmental impact caused, whether in the exploration or disposal of materials. Such utensils are discarded incorrectly by the general population who ignore the harmful effects of this neglect due to a lack of environmental awareness and ignorance of the value of these discarded objects when recycled.

> Among the themes that most concern humanity in this third millennium, the environmental issue is the most intelligent. Not many people have yet realized its severity. Without the preservation of nature, all other human afflictions will lose their reason for being, simply because there will be no more human life on the planet. (BRAZIL; SANTOS, 2007)

An issue that has been gaining notoriety is the preservation of the environment through the actions of human beings and sustainability. In this context, materials discarded or found in nature or in landfills need to be removed for recycling and the most common way to remove them is through recyclable material collectors, who are often hampered in their function by unsanitary conditions, arising from the incorrect disposal of materials such as batteries, organic and hospital waste mixed with recyclables.

Collectors separate plastic packaging by removing the label and lid and baling it to sell it, however, the majority of those who work in this role have their knowledge on the subject acquired through practice, increasing the difficulty in separating different types of plastic by are unaware of classification criteria for this type of material.

Therefore, the difficulty of transporting the plastic carried out by the collector must be taken into consideration, as, due to the large volume per kilogram, large spaces are needed to transport a small mass. This way, the ideal would be to disseminate this information among the population, from children to the elderly, collectors and selective collection cooperatives, in order to develop appreciation and collection for all types of materials and not privilege some, causing these materials non-privileged people return to the value chain.

Advances in the creation of new technologies applied to plastic recycling aim to produce a material to replace virgin plastic, thus reducing the exploitation of mineral resources and subsequently the environmental impacts caused by the exploitation and inappropriate disposal of waste. (LOUREIRO, 2004). The disposal of materials in nature that take many years to decompose, such as rubber, glass, plastic, metal, among others, is constant and is growing more and more. These materials are everywhere in the seas, rivers, forests, mountains and are consumed by the animals that live in them, harming, maiming and often killing them. Such materials can also be found on beaches and streets and because they are small, due attention is often not given to collecting and disposing of them in the correct place, such as chewing gum, bottles, bottle caps, cans, rubber slippers etc.

In the following table, it is possible to observe the time it takes for waste to decompose (Table 1), and the notable importance of collecting, disposing and recycling correctly.

Materials	Decomposition time
Paper	From 3 to 6 years
Clothes	From 6 months to 1 year
Cigarette filter	Over 5 years
Painted wood	Over 13 years
Nylon	Over 20 years
Metal	Over 100 years
Aluminum	Over 200 years
Plastic	Over 400 years
Glass	Over 1000 years
Rubber	Undetermined

Tabele 1: Decomposition time

Source: MEC, 2005

JUSTIFICATION

The project was designed and chosen after research carried out on sustainable tiles so that it could somehow contribute to Civil Engineering, providing means that would impact the environment with the collection of incorrectly discarded materials.

The development of the project sought to raise awareness among the population and professionals in the field of Civil Engineering, that sustainable means can be used without losing the quality of the materials collected, creating an even greater responsibility for the sector regarding solid waste and even construction waste. This piece suggested in the work also contributes to reducing the volume of discarded plastic, creating sustainable use and adding value to this material without degrading the environment.

GOALS

GENERAL GOAL

Produce in the laboratory a tile made from recycled HDPE plastic that has physical-chemical characteristics with quality equal to or greater than conventional tiles, being financially viable compared to those on the market, reducing the volume of it in nature.

SPECIFIC GOALS

- Produce in the laboratory a tile made from recycled plastic with HDPE packaging.
- Obtain efficient selective household collection of plastic packaging.
- Develop methods for treating this material, preparing it for its new purpose.
- Design and manufacture a practical and low-cost way to produce tiles.

HYPOTHESIS

It is possible to produce an efficient tile for use in civil construction from HDPE recycling, without compromising the properties required for resistance, thermal insulation, impermeability and aesthetic appearance, and also adding value to selective collection in a to contribute to raising awareness among the population financially and ecologically?

BRIEF HISTORICAL REPORT

Historically, according to the Brazilian Association of the Pet Industry – ABIPET (2010), in 1941 the first sample of pet resin was developed by the English Whinfield and Dickson, as in the Second World War the prevalence was in the textile industry and at the time it was already suffering from shortages.

Taking into consideration the needs of the period, alternatives were sought for textile production, thus, polyester presented itself as an excellent substitute for cotton, which at the time had all fields destroyed by the war, thus, polyester fulfilled the function well until nowadays, including from recycled PET bottles.

According to Barros (2014), the concern was due to the difficulty in disposing of materials that are difficult to degrade, one of which was Pet, which, being 100% recyclable, did not have its destination properly correct, as it was faced with a lack of selective collection. in several cities across the country, as well as the lack of incentives for recycling.

As Teodósio (2006) points out, the irregular disposal of pet bottles can cause several complications such as obstructions of galleries, rivers, streams, rainwater drainage systems, causing a greater volume of floods, in case of disposal in a landfill, it seals the layers of decomposition, damaging the circulation of gases and liquids.

According to Abipet (2010), the uses of recycled pets can be varied, one of them is the textile industry in the manufacture of clothes and blankets, in the production of ropes and broom bristles, paints and varnishes and even alternative materials used in civil construction such as paints. and varnishes, tiles, pipes and connections for sewage composition in buildings and residences.

For Barros (2014), the use of recycled PET bottles in construction comes in different forms and has high tensile strength and durability. Recycled products from PET bottles used in construction can be used in the manufacture of wall and roof panels, in filling slabs, in blocks for creating masonry seals with thermo-acoustic insulation, among others.

SUSTAINABILITY

According to the UN World Commission on the Environment, sustainability is directly linked to the term "sustainable development", or the ability to satisfy the needs of the present without compromising the ability of future generations to satisfy their own needs (CMMAD, 1988).

For Yemal et al (2011), sustainable development is only achieved through fundamental changes in the different ways of thinking, acting, living, producing and even consuming, as concern for the environment has become greater for world order countries and One of the main topics discussed is the civil construction sector, which produces major environmental impacts.

According to Bernardo (2012), sustainable construction must be planned for low use of vegetation areas and generation of less waste in the construction and operation phases or even consume less water and energy, this way, civil construction has great responsibility regarding the impacts produced and discarded on the environment, and therefore, rethinking the use of materials and spaces is important.

Currently, within the civil construction area, several products are already obtained from recycled or sustainable materials, which, when replaced, make the works cheaper and contribute to the environment. This way, we can usually see reforestation wood, adobe brick, tiles ecological, concrete blocks made with Styrofoam and PET, among others.

Considering the above, it is clear how important a sustainable project is in civil construction and how valuable it can be to reduce the waste produced. Next, the types of plastics and their names, recycling, methodology and description of the tile project in a sustainable way for civil construction will be presented.

PLASTIC AND ITS TYPES

The first synthetic plastic in history was discovered at the beginning of the 20th century. The name "plastic" comes from the Greek word "plástikós", which in Latin gave rise to the adjective "plasticus" which means "can be molded". Over the years, this material was improved based on research that identified possibilities in varying the characteristics of each polymer. Thus, the division of plastics into thermoplastics (recyclable) and thermosets (non-recyclable) emerged.

"The plastic collected from urban waste for recycling and reuse is basically composed of thermoplastics" (MORAES et al, 2010, apud PIVA & WIEBECK, 2004, p. 2). Figure 1 shows the average distribution of the types of plastics found in discarded waste.

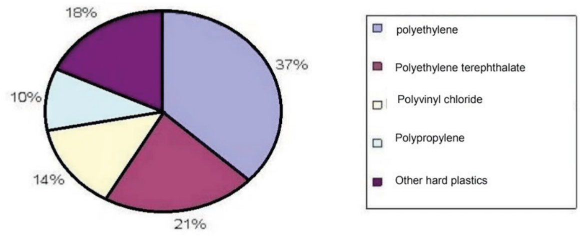


Figure 1: Distribution of plastics in discarded waste

Source: PIVA & WIEBECK, 2004

Recyclable plastics are represented through a code used throughout the world in order to make identification easier. According to ABNT – Brazilian Association of Technical Standards, in the NBR-13230 standard – Symbologies Indicated in the Recyclability and Identification of Plastics. Identification occurs through a number listed for each recyclable polymer or by its usual name and indicating some of the most common uses of each polymer. Identification of plastics and symbols according to ABNT (Figure 2).

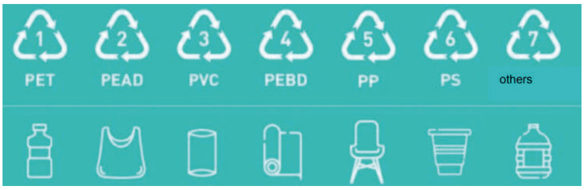


Figure 2: Symbols

Source: ``*Mais Polímeros*``, 2020

PET (Polyethylene terephthalate)

PET is formed by the reaction of terephthalic acid and ethylene glycol. It is used in the manufacture of jars and bottles for food, such as soda and water bottles, medicine packaging, among others. It is a transparent, unbreakable, waterproof and light material.

Its disadvantage is that it is made from petroleum, so when mixed with some materials, it becomes unviable for recycling.

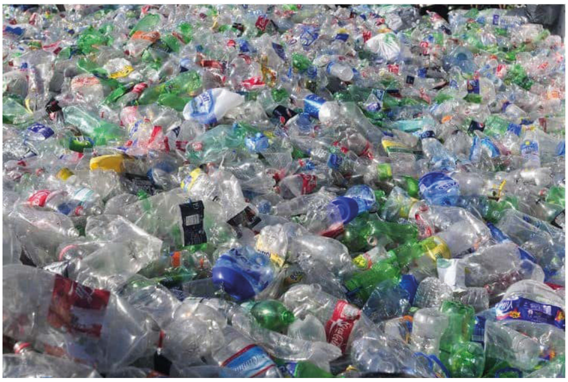


Figure 3: PET material

Source: ``*Tunes Ambiental*``, 2018

PEAD (High density polyethylene)

HDPE is used to manufacture lids and packaging such as bottles for fabric softeners, bleaches, shampoos, detergents and automotive oils, supermarket bags, jars and household items.

It can be obtained from petroleum or vegetable sources (green plastic). It has chemical resistance, is waterproof, rigid, resistant to low temperatures, light and unbreakable.

Figure 4: HDPE material

Source: ``*Conhecimento Científico*``, 2021

PVC (Polyvinyl chloride)

PVC is made up of 43% ethylene and 57% chlorine. Its characteristics are to be rigid, transparent (when desirable), unbreakable and waterproof.

It is widely used in construction, in water and sewage pipes, and is also found in packaging such as edible oils, mineral water and mayonnaise jars. Furthermore, it is widely used in more resistant products, such as traffic cones, toys and gutters.

Figure 5: PVC material

Source: ``*Tunes Ambiental*``, 2018

PEBD (Low Density Polyethylene)

LDPE, being flexible, is widely used. It is also lightweight, transparent and waterproof. In addition to being derived from petroleum, it can be obtained from vegetable sources (green plastic).

Used in the manufacture of bags for supermarkets and stores, packaging for milk and other foods, garbage bags and hospital supplies.

Figure 6: LDPE Material

Source: ``*Ambiente Brasil*``, 2018

Journal of Engineering Research ISSN 2764-1317
DOI https://doi.org/10.22533/at.ed.3174172421069

PP (Polypropylene)

PP is produced from propylene gas. Its characteristics include being unbreakable, transparent, shiny, rigid and resistant to temperature changes, in addition to preserving aromas well.

It is used for food packaging, industrial and civil construction products, such as ropes, pipes, wires and cables. It is also used in bottles, beverage boxes, auto parts, pots and housewares. Its properties are similar to polyethylene; however, it has a higher softening point.

Figure 7: PP material

Source: Plastiflan, 2016

PS (Polystyrene)

PS has the characteristics of low cost, lightness, thermal insulation capacity, flexibility and is workable under the action of heat, which leaves it in liquid or paste form.

It is used in the manufacture of pots, flasks, parts of household appliances, such as the inside of refrigerator doors, toys and some disposable products, such as plastic cups and razors.

Figure 8: PS Material

Source: Plastiflan, 2016

Others

They are plastic resins. They can be found in multilayer packaging for cookies, snacks, baby bottles, CDs, DVDs, milk cartons and some household items.

Figure 9: Other kinds of plastic

Source: ``*CEMPRE*``, 2020

RECYCLING

Nowadays, although there is no immediate solution to the toxic sea of plastics in our ocean, recycling, in turn, is the best answer to the problem according to experts, as current processes do not address the emerging needs for of recycling.

According to data from the UN (United Nations), the world produces around 300 million tons of plastic waste each year, and to date, only 9% of all plastic waste generated has been recycled and 14% is collected for recycling. In total, around 8.3 billion tons of plastics have already been produced in the world, half of which in the last 13 years, plastic waste can take 20 to 500 years to decompose, and even then, it never completely disappears. Microplastics are present in every corner of the planet, from the peak of Mount Everest to the bottom of the oceans. Still, of all the plastic discarded so far, 12% has been incinerated, and only 9% has been recycled and the rest has been discarded in landfills or released into the environment (UN, 2021).

Figure 10: Garbage Collector in Ghana

Caption: In Accra, Ghana, a plastic waste collector takes the plastic he recovered to a landfill, where intermediaries will buy it. Photo Muntaka Chasant (Ghana)/Plastic is forever. Source: brasil.un.org/30/06/2021.

The plastic recycling process can be carried out in three ways: physical or mechanical recycling, chemical or resin recycling, and energy recycling. Each one has its own characteristics and different uses:

Mechanical recycling

It is the most common type of plastic recycling. The process begins with collecting the material, both from industrial waste and domestic collection. The plastic is then cleaned and sorted to analyze what will be used. After that, the recycling process starts. All material is reduced to small grains, without modifying its physical properties, which will serve as raw material for the production of other products. This type of recycling is seen in selective collection cooperatives.

Chemical or resin recycling

This is a more complex process, as the plastic undergoes a chemical transformation capable of returning it to its previous condition. This procedure is known as reverse logistics. The plastic object returns to its initial condition through chemical manipulations, which involve the application of solvents, acids, heat, among other chemical processes.

Energy recycling

The collected material is transformed into thermoelectric energy, in a process in which recyclable plastic is subjected to high temperatures, and the steam that results from this incineration is converted into energy capable of moving propellers connected to turbines. From this movement, for every 1,000 kilos of recycled plastic, 640 KWh are produced.

The process occurs due to the composition of the plastic, which is derived from petroleum, capable of producing enough energy to replace diesel oil and other fossil fuels when heated.

Using one of the forms of recycling to reuse material that has already been used and is about to be discarded, helps the environment and allows for a more rational and sustainable use of materials.

The process begins with the collection of plastic, which can be found on beaches, seas, rivers, streets and household waste. It is divided into: selective collection, in which some municipalities have selective collection of urban waste in force, which means that citizens are advised to separate their waste, packaging it separately from organic waste and recyclables; directed collection, which offers an alternative to collection in municipalities that do not have selective collection. Its application involves raising awareness among the local population about the separation of recyclable material, delivering it to collection points or with a fixed date for home collection, and being able to use the collected material as "exchange currency" (which can be exchanged for money or credits in commercial establishments in the municipality) generating value for the material and helping people and local businesses. Afterwards comes the printing, which is separated by color, and the pressing that selects the post-consumer packaging, these must be pressed and tied, to reduce their volume and facilitate available transport.

Figure 11: Selective collect

Source: ``*Prepara ENEM*``, 2021

TILES

There is a wide variety of materials used to manufacture tiles on the market, with their own styles, specifications and characteristics.

Therefore, it is essential to understand the basic differences between each tile, in order to choose the most suitable one for your construction. (ARCHTRENDS, 2020).

TRADITIONAL TILES

Ceramic tile

It is the most common in residential projects. It offers thermal comfort and is efficient when sealing the roof. Also known as "clay tiles", they can be natural or glazed, the latter being more durable.

Figure 12: Ceramic Tile

Source: ``*Viva Decora*``, 2021

Concrete tile

It has good durability and thermal comfort. This model does not have a covering enamel, which is why the application of resin is recommended for protection and waterproofing.

Figure 13: Concrete Tile

Source: ``*Tua Casa*``, 2021

PVC tile

It is light and versatile, its main advantages are the fact that fewer pieces are needed per m², as they are large and resistant, reducing the chances of material loss. Furthermore, they offer good acoustic and thermal insulation.

Figure 14: PVC Tile

Source: ``*Tua Casa*``, 2021

Fiber cement tile

They are cheap and lightweight models, normally used on roofs with a low slope, such as in industries, warehouses, garages and businesses.

Figure 15: Fiber cement tile

Source: ``*Decor Fácil*``, 2021

Metallic tile

They are the most used for covering gaps as they come in larger versions. One model is galvanized roofing or zinc roofing, which goes through a process that helps protect the steel against corrosion. Another option is the "sandwich tile", which has a "filling" of Styrofoam or expanded polystyrene foam to help with the thermal and acoustic comfort of the roof.

Figure 16: Metallic tile

Source: ``*Viva Decora*``, 2021

Glass tile

It is the most used to allow better natural lighting, and can be produced in the same format as ceramic or concrete tiles, and can also be used for outdoor environments.

Figure 17: Glass tile

Source: ``*Decor Fácil*``, 2021

RECYCLED MATERIAL TILES

With the increased focus on sustainability, there are now some models made from recycled material on the market.

PET tile

It is produced from recycled PET bottles, is light and very resistant, being able to withstand high temperatures. As it is non-porous, this option has less permeability, reducing the chances of mold development, and can be found in some models similar to ceramic tiles.

Figure 18: PET Tile

Source: ``*Viva Decora*``, 2021

Ecological tile

It is produced from layers of vegetable fibers waterproofed with bitumen and protected with resin, making it easy to install and lightweight.

Figure 19: Ecological Tile

Source: ``*Tua Casa*``, 2021

METHODOLOGY

The material used to make the prototype comes from household waste, collected in the region. This collected material was fragmented in an industrial crusher, reaching a suitable particle size to reach the melting point more easily. The melting point was reached with the help of an oven in the laboratory of the Santa Cecília University – UNISANTA. With the material in plastic conditions, the tiles were molded into a wooden shape and a metal shape, designed and manufactured by the authors themselves. Seeking to obtain pre-established characteristics. Tests will be carried out with the prototypes to understand the characteristics of the tiles.

PRODUCTION METHOD

A theoretical research was carried out on the relevant subjects, enabling a bibliographical review that involves the search for the objectives of the work. The material used to make the prototype comes from household waste from friends and family, collected in the cities of Santos, Cubatão and the region. After collecting the material, a distinction was made according to the type of plastic to separate only the HDPE plastic, after separation, the recyclables went through the cleaning process, the collected material is manually washed with soap and water (to remove impurities such as earth and sand, and dry the material).


Figures 20 and 21: Materials collected

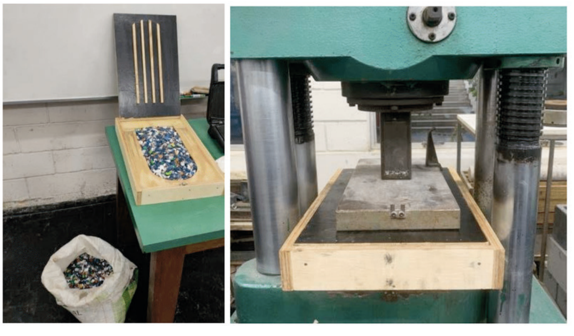
After drying, the washed material passes through an industrial crusher (equipment for crushing the material into smaller grains, to obtain an even fusion).

Figures 22 and 23: Crusher used

After being fragmented, it was placed in a greenhouse at the Santa Cecilia University laboratory (simple equipment that allows the plastic to be recycled through heating, where it melted and plasticized, and could then be shaped as needed) and thus injected into a form made of wood with the design of a Germanic tile, which was designed in AutoCAD software with the specified dimensions and compressed in a universal press also from the laboratory.

Figure 24: Shredded plastic **Figure 25:** Greenhouse used

Figures 26 and 27: Preparation process for tile modeling



Figures 28 and 29: Wood-shaped tile modeling

Figure 30: Weighing the first tile

The search for the best design for the tile began with the 1st prototype, after which the shape was changed to metal, to improve the process and aspects such as weight and aesthetics.

Figure 31: Metal form for tile shaping

Figure 32: Tile heating and shaping

Made with 280 pats or less than one kg of HDPE packaging, material used and removed from the environment, to manufacture a tile, to serve as a base.

Figure 33: Material needed to make the tile

Figure 34: Weighing the material

Figure 35: Weighing the second tile

They will be qualified with resistance, tightness and durability tests, following the requirements of ABNT and ASTM standards, using the Civil Engineering laboratory at Santa Cecilia University, with the aim of verifying quality metrics with market or organization standards. be achieved described in table 2 below.

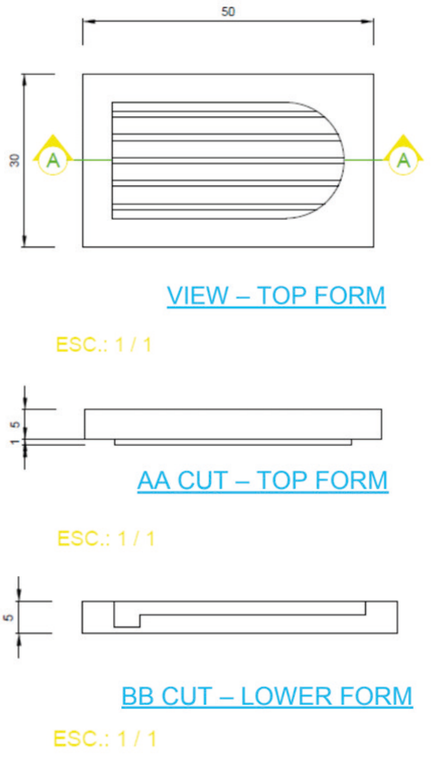
Applicable Standards	ABNT Standard/QMS Procedure
ASTM D 256-10 Standard: ISO 180:2000 Resistance	International standard that establishes the method and standard requirements for determining the impact resistance of plastic (eco-friendly tiles), through tests with a test specimen.
ASTM D 638-14 standard. Traction	This International Standard establishes the requirements necessary to check tile traction on an Instron Model 1172 Universal Testing Machine.
ASTM D1238-13 and Norm ASTM D3641 –15: Fluidity and Temperature Index	International standard that establishes the conditions that must be met to verify the temperature level at which the plastic "tile" could withstand both in the injection molding machine and exposed to solar temperatures.
NBR 15575 (ABNT, 2013): Performance of residential building	This Standard presents performance criteria for: habitability (visual comfort, acoustic comfort, hydrothermal comfort, accessibility, functionality, healthiness, tightness, tactile comfort and ergonomics); sustainability (durability, maintainability and environmental performance) and safety (structural, fire and use)

Table 2: Quality metrics

Source: BACELAR, 2014

METHOD FOR MAKING THE TILE

Three molds were built, two made of wood and one of metal, with the shape based on a Germanic tile. The wooden molds were the first to be designed, as they served as a test for the desired shape and dimensions for the real mold and reduced the likelihood of simple errors, without damaging the budget with unnecessary and unforeseen expenses. The aforementioned mold will not be the same for modeling the tile, as the plastic will be introduced at high temperature and compressed to remove the voids. Therefore, two wooden molds were built in case any unforeseen circumstances occurred. Through the first prototype, we made the metal mold, which better met the desired specifications for aesthetics, quality, resistance and economy, as the material melts and is already molded into its own shape inside the greenhouse. Tests on the fabrication are already being carried out and data, resistance, tightness and thermal insulation tests will be collected.



Journal of Engineering Research ISSN 2764-1317 DOI https://doi.org/10.22533/at.ed.3174172421069

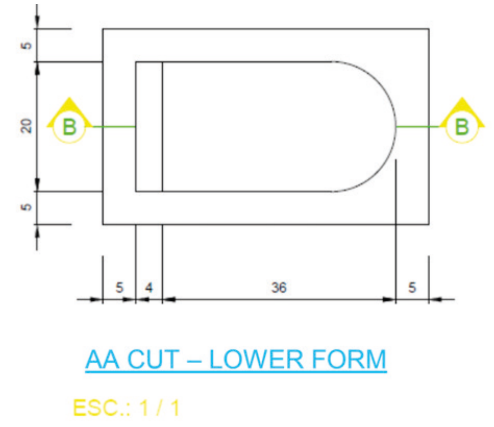


Figure 36: Shape Design Views

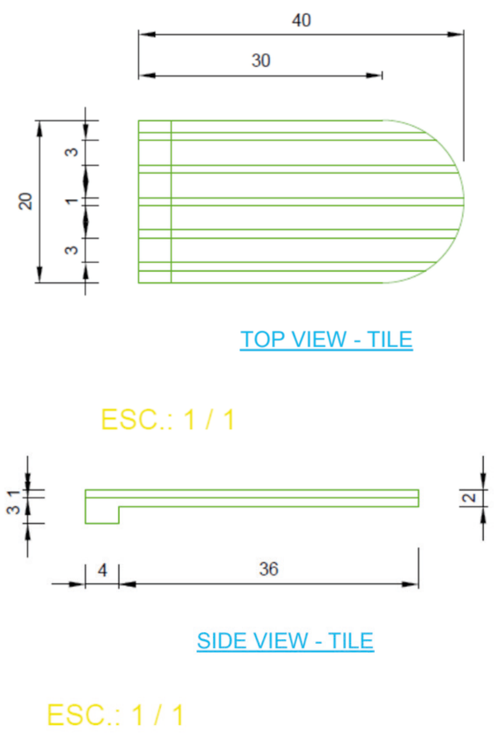


Figure 37: Tile Project Views

EVIDENCES OF CONCLUSION

This work sought to present sustainable solutions for civil construction, in order to preserve the environment, river sources, sea arms, beaches, among many other points spread across the city of Santos, Cubatão and the like, as population growth increased the difficulty in controlling and raising awareness for the correct disposal of recyclable materials.

The tile project was designed after research and an interest in preserving the environment, bringing a real sustainable means for use in civil construction.

Initially, it is believed that the prototype will meet all expectations, bringing improvements in terms of reducing impacts caused by the disposal of materials in the environment. From the preliminary results, it is concluded that it is possible to make tiles with recycled HDPE plastic, even if handcrafted, generating a quality product from materials found in household waste.

Finally, it is believed that sustainable construction can bring several environmental, economic and social benefits to individuals, in addition to quality of life while preserving the environment.

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