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Printed thermoplastic modular piece, P.T.M.P.

Piezas termoplásticas modulares, P.T.M.P.

SANDRA MOYANO SANZ
Escuela Técnica Superior de Edificación UPM., D090 de Tecnología de la Edificación, Av. Juan de Herrera, 6, 28040 Madrid, España,
d090.dpto.tecnologia.edificacion@upm.es
E-mail: sandramoyanosanz@yahoo.es

MERCEDES VALIENTE LÓPEZ
Escuela Técnica Superior de Edificación UPM., D090 de Tecnología de la Edificación, Av. Juan de Herrera, 6, 28040 Madrid, España,
d090.dpto.tecnologia.edificacion@upm.es
E-mail: mercedes.valiente@upm.es

◊ It is important to know the new technologies to be able to move with them, and the 3D impression gives us the possibility to improve constructive elements, which by their importance, and their simplicity, are considered essential within the field of construction.

This research tries to design a modular part suitable for construction, with new materials and manufacturing processes. Polymers and 3D printing are the key elements in the process. It is about implanting a new model of modular part that is able to replace the conventional brick. With this research, we want to make known the new construction processes derived from 3D printing and how we can improve the existing technology. The main objective is to design a modular part, using additive manufacturing systems and plastic materials. Then we are going to determine the physical characteristics that the pieces must have, and the geometric possibilities that the manufacturing process allows us, as well as the materials that the pieces will be made. These pieces will be subject to all the actual tests to ceramic pieces, according to the current standard. Additionally, we will analyze the results obtained and compare them with an expensive ceramic brick to assess the advantages obtained. Finally, we will determine some conclusions derived from these investigations, and propose new study proposals. With this research, we intend to demonstrate that, although conventional brick are basic elements of construction and fulfils its functions perfectly, it is time to adapt the new technologies to the constructive methods.

3D printing; Modular printed parts; Thermoplastic brick; Additive manufacturing

◊ Es importante conocer las nuevas tecnologías para poder servirnos de ellas, y la impresión 3D nos aporta la posibilidad de mejorar los elementos constructivos, que, por su importancia y simplicidad, son considerados esenciales dentro del sector de la construcción.

Este estudio trata de diseñar una pieza modular apropiada para la construcción mediante nuevos procesos de producción y nuevos materiales. Los polímeros y la impresión 3D son los elementos clave del proceso. Además, se estudia implantar un nuevo modelo de pieza modular que sea capaz de sustituir al ladrillo convencional. Con esta investigación queremos divulgar los nuevos procesos asociados a la impresión 3D y como podemos mejorar la tecnología existente. El objetivo principal es diseñar una pieza modular, usando sistemas de fabricación aditiva y materiales plásticos. Posteriormente vamos a determinar las características físicas que deben tener las piezas y las posibilidades en cuanto a la geometría que el proceso de producción nos permite, además de los materiales que compondrán las piezas. Estas piezas serán sujeto de todos los test estándar aplicables a las piezas cerámicas. Adicionalmente, analizaremos los resultados obtenidos y los compararemos con piezas de ladrillo de alta calidad para asegurarnos de las posibles ventajas obtenidas. Finalmente, haremos algunas conclusiones derivadas del estudio, y se harán propuestas para nuevas vías de estudio. Con la investigación tenemos la intención de demostrar que aunque los ladrillos convencionales son elementos constructivos básicos, que cumplen su función perfectamente, es momento de adaptar las nuevas tecnologías a los métodos constructivos.

Impresión 3D; Pieza modular impresa; Ladrillo termoplástico, Producción aditiva

1. INTRODUCTION

The three-dimensional impression, increasingly common in our society, tries to reflect objects using the method of adding the material, by superimposing successive layers, thus creating an object in three dimensions [4].

There are numerous materials that are used in 3D printing as well as different printing techniques. We have chosen Fused Deposition Modeling (FDM) or Fused Filament Fabrication (FFF) [5].

The additive technique of molten deposition is a technology that consists on depositing molten polymer on a flat base, layer by layer. The material, which is initially in solid state stored in rolls, melts and is expelled from the nozzle in tiny threads that are solidifying as they take the shape of each layer [6].

In the market there are more than 60 types of materials for 3D printing, among which we can stand out:

- Polylactic acid (PLA).
- Laywoo-d3, composite wood / polymer similar to PLA.26.

- Acrylonitrile Butadiene Styrene (ABS).
- High Impact Polystyrene (HIPS).
- Polyethylene Terephthalate (PET).
- Thermoplastic Elastomer (TPE).
- Nylon, the most used.

The filaments are characterized by the diameter in millimeters and they are generally sold in reels by weight (kg). In addition to those mentioned above, there are other types of filaments, which due to their mechanical features create the possibility of printing objects with different applications.

This is the case of FILAFLEX, which is a plastic compound to which is added a chemical agent (plasticizer), to increase its flexibility and reduce the melt temperature and viscosity that allows the 3D printers to melt it and give it the desired shape, leaving the final product as a consistent piece that presents as main property to highlight its flexibility. Quality that other compounds lack, such as the PLA or plastic of the ABS coils if they are in a pure state [7].

In our case, we want to work with the combination of ABS and FILAFLEX, because the physical and mechanical properties of both filaments make possible the creation of pieces suitable for construction, which we will explain later. In order to combine such filaments, we need the printer by deposition of the molten material to have at least two print heads.

2. OBJETIVES

We propose a series of objectives to carry out this investigation.

2.1 GENERAL OBJECTIVES

The main objective is to design a functional part, suitable for building construction in modules, to improve the features of existing bricks, and to provide all the advantages of new 3D printing technologies, in the field of building.

These modules are equivalent in size to the set of four bricks in facade facing, and will be printed in ABS material almost in its entirety, except for a vertical and horizontal membrane of FILAFLEX, which corresponds to the sealing of joints.

As for the method of assembly, it is done by tongue and groove in the vertical joints and union by means of staples in the horizontal joints, how can we observe in figure 1.

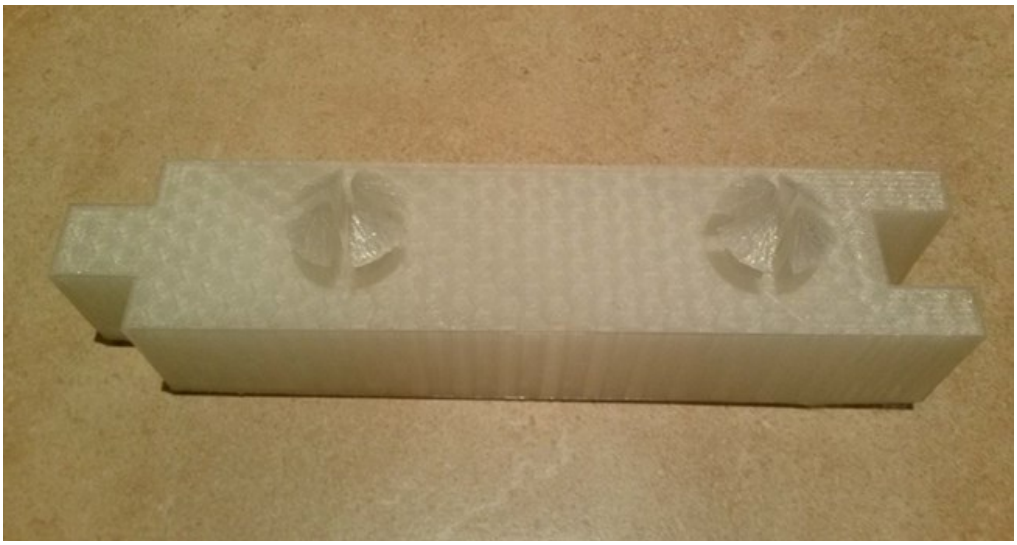

Figure 1: Thermoplastic modular piece

By means of this method of connection, and by the arrangement of the lower holes of the pieces, the installation can be done either "staggered" or "skirting", to guarantee the stability of the whole.

The design of the parts is sought, the speed of execution, the value for money and the ease of acquiring special parts for the realization of the system.

As for the study of the features, these pieces have the peculiarity of both the material with which they are printed and the execution process, and this makes them acquire special features that traditional bricks do not have. Among others, the modular part consists of inner cells that create air chambers that improve its acoustic and thermal features, while lightening the weight of the piece and can thus increase its dimensions.

Once the piece is designed and printed, the laboratory tests are performed for both bricks and plastics, and the results are compared with those of a ceramic brick to be used.

We highlight, among others, the different tests that occur in ceramic pieces.

- Dimensions.
- Face planning.
- Parallelism of faces.
- Geometry and shape.
- Apparent density.
- Absolute density.

- Compressive strength.
- Thermal resistance.
- Resistance to ice / thaw.
- Water absorption.
- Suction.
- Expansion by moisture.
- Soluble salt content.
- Reaction to fire.
- Adherence.

Once the physical and mechanical features of the pieces are known, we will proceed to set new uses, both in the building and construction fields.

2.2 SPECIFIC OBJECTIVES

As regards the specific objectives, in order to design these pieces,. We must, in addition to the general dimensions, size the number and dimension of the inner cells to improve their basic features, the transversal division of the staples, to guarantee their rigidity, the printing parameters, both to avoid warping[1] and to streamline printing processes.

We must also determine the type of material for printing. In our case we have chosen ABS for the following features: [9]

- It is a very impact resistant plastic, making it suitable to withstand inclement weather.
- It is a plastic that undergoes exposure to relatively high temperatures, becomes deformable or even melting, while in case it cools down sufficiently it hardens.
- It is composed of three blocks, acrylonitrile, butadiene and styrene, so it is called terpolymer.
- Each of the three blocks has different features. The acrylonitrile stiffness, resistance to chemical attacks, hardness and stability to high temperatures. Butadiene, temperature toughness when it is especially low and impact resistance; and styrene, mechanical strength, stiffness, gloss, hardness.
- This mixture of properties makes the final product of great application for the construction and above all, for the manufacture of elements exposed to the elements.
- Its resistance to extreme temperatures, especially when these are of low zero make it a particularly interesting material for cold environments, staying unchanged where others become brittle.
- In addition, it absorbs little water and is easily coated with metallic layers because it is very receptive to metal baths.
- It can also be pigmented in most colors to get a good finish and is non-toxic.
- Not highly flammable, but maintains combustion.

As for FILAFLEX:

- It is the most elastic filament of the market, reaching to reach a 700% of stretch until the break.
- Has a high coefficient of friction.
- It is resistant to gasoline, solvents and acetone.
- Nontoxic, but not approved for medical or food use.
- It does not emit smells; it is totally odorless and does not produce toxic gases.

It is a suitable material, to solve the encounters between modular pieces, to absorb the movements relative to the contractions and dilations of the changes of temperature and to avoid the humidity, either by condensation, capillarity or water leaks.

The binding method of P.T.M.P. (Printed thermoplastic modular piece) is performed both vertically and horizontally to ensure stability of the assembly and avoid movement in any plane.

As mentioned above, for the execution of said pieces, it is necessary to use a printer by deposition of the molten material consisting of two extruders.

It is about depositing or melting the plastic thread through two nozzles without stopping the machine and without any stops during the printing. That is, the same double extruder has two filament outputs to print layer by layer two materials at the same time. It is printed with a nozzle and when the 3D model requires it, the printer calls the second extruder and it automatically starts printing [8].

This technique is very useful, if one wants to print a piece in multiple colors; with several materials or even if one of them serves as a water soluble support material.

3. THEORETICAL FRAMEWORK

This research aims to improve the properties of traditional bricks, so that in the future, it will be more cost effective to replace them with P.T.M.P.

General properties of ceramic materials: [10]

- They're hard.
- Noncombustible.
- Nonrusting.
- High resistance to high temperatures.
- Thermal isolation.
- Electrical isolation.

[1] Warping: This is due to the contraction, the material exits the extruder at 260 degrees Celsius, collides with the platform which is about 60, and cools, creating a contraction. The center material pulls away from the corners, causing the corners to rise. In a well calibrated printer and in a normal environment, without direct air currents, warping should not occur, except for parts with a large base surface.

- Great resistance to corrosion and the effects of erosion.
- High resistance to almost all chemical agents.
- Low resistance to stresses.
- Low elasticity.

Additives used in ceramic materials: [3]

- Degreasers, especially considering blast furnace slag and fly ash from a thermal power plant.
- The addition of sodium chloride which, in certain cases, improves drying and combat the caliche explosion.
- The addition of manganese dioxide, frequently used in the production of artificially aged products.
- The addition of crushed limestone, which allows us to reduce the dilations due to humidity.
- The addition of lime, to harden very damp clays.

4. PROPOSED METHODOLOGY

It is about carrying out some guidelines in research, in order to obtain the aforementioned objectives.

- Design of the piece.
- Study of physical and mechanical features.
- Solve warping problems.
- Print the parts needed to carry out the tests.
- Perform laboratory tests.
- Data collection of the results obtained.
- Analysis of the data obtained.
- Comparison of results and requirements of the standard.
- Improve initial conditions.
- Propose new uses.
- Raise future research lines.
- Last conclusions.

5. DEVELOPMENT OF THE STUDY

It is necessary to plan in detail the material resources necessary for the realization of the tests, as well as their order, depending on whether it is destructive or non-destructive tests, to economize the process and collaborate with the sustainability of the same.

Standards:

- CTN 136 - CERAMIC MATERIALS OF COOKED CLAY FOR CONSTRUCTION

  Ceramic clay pieces and products for construction such as: bricks, blocks, tiles, slabs and boards, in their aspects of definitions, classification, specifications and test methods. [1][2]

International relations:

a) CEN / TC 125 / WG 1 / TG 1 Masonry. Masonry products. Ceramic Products.

b) CEN / TC 125 / WG 9 Masonry. Dome of cooked clay.

c) CEN / TC 128 / SC 3 Discontinuous installation products for roofs and walls. Clay tiles.

d) CEN / TC 178 / WG 3 Units for pavements and curbs. Ceramic products.

Norma	UNE-EN 772-19:2001
Título español	Métodos de ensayo de piezas para fábricas de albañilería. Parte 19: Determinación de la dilatación a la humedad de los grandes elementos de albañilería de arcilla cocida, perforados horizontalmente.
Título inglés	Methods of test fot masonry units - Part 19: Determination of moisture expansion of large horizontally perforated clay masonry units.
Título francés	Méthodes d'essai des elements de maconnerie. Partie 19: Détermination de la dilatation a l'humidté des grands elements de maconerie en terre cuite pérforés horizontalement.
Fecha Edición	2001-01-31
Versión confirmada en fecha	2005-04-24
ICS	91.100.15.15-20 / Productos y materiales de arcilla cocida
Comité	CTN 136 – MATERIALES CERÁMICOS DE ARCILLA CICIDA PARA LA CONTRUCCIÓN
Equivalencias Internacionales	EN 772-19:2000 Idéntico

Figure 2: Spanish Association for Standardization and Certification

6. COMPARATIVE STUDY

Comprehensive, orderly and concise data collection of all the information in the process is required.

These data will be compared with those found in the regulations, and the difference between the two data will be evaluated, both in numerical index and in percentage, in order to arrive at a correct conclusion.

7. CONCLUSIONS

With this new execution system, we can print on-site, every piece required at any time. Thanks to the properties of ABS, we can improve the conditions of traditional brick.

With the new design of the pieces P.T.M.P. we can streamline construction processes and save costs. One of the most important data to know is the compressive strength of the product, and yes, it can behave like a load element.

The possibility of placing them dry, eliminates a game of execution and makes the construction process simpler, with what this entails. If the pieces P.T.M.P. are more insulation, they will also be more sustainable. Low cost of construction in large quantity.

The main disadvantage is that it does not allow placement error, without the destruction of the piece. In contrast, these pieces are called foolproof , they do not admit an error in the placement between them, except for staking errors.

This innovative technique for the manufacture of parts allows it to be very accessible, and for anyone with minimal computer skills to have the possibility to manufacture the part they want at any given time. So you do not need qualified staff for your printing and placement.

With this information we can propose a series of hypotheses based on data that serve as the basis for initiating an investigation.

The pieces P.T.M.P. They may be:

- More affordable, when it comes to special pieces in meetings.
- More agile construction processes.
- Improvement of resistances.
- No bonding mortar required.
- More insulation.
- More sustainable.
- 100% recoverable.
- Lower cost of production on a large scale.
- Less manufacturing power is used.
- Printing in different colors, even translucent.
- Some difficulty in inserting installations inside.
- Lower transport costs.

These hypotheses remain unresolved from the results of the laboratory tests, and their subsequent comparative analysis with a traditional brick.

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