UNIVERSIDAD DE VALLADOLID

ESCUELA DE INGENIERIAS INDUSTRIALES

Grado en Ingeniería en Diseño Industrial y Desarrollo de Producto

Técnicas de modelado en arcilla. Diseño y fabricación de elementos modulares de fachadas.

Autor:

Garayo Fernández, Lucía

Responsable de intercambio:

Fernández Villalobos, María de las Nieves

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TFG REALIZADO EN PROGRAMA DE INTERCAMBIO

TÍTULO:	**Clay modelling techniques. Design and manufacturing of modular façade elements.**
ALUMNO:	**Lucía Garayo Fernández**
FECHA:	**7 de junio de 2024**
CENTRO:	**Escola de Arquitetura, Arte e Design**
UNIVERSIDAD:	**Universidade do Minho**
TUTOR:	**Bruno Figueiredo**

RESUMEN

La presente investigación se desarrolló en el contexto de la unidad curricular “Design Industria” del segundo semestre del tercer año de la carrera de “Product Design” de la Universidade do Minho.
Esta unidad curricular tiene como objetivo aproximar a los estudiantes al mundo laboral a través de una empresa y darles la oportunidad de aplicar lo que han aprendido a lo largo de sus estudios. Las prácticas tuvieron lugar en el “Advanced Ceramic Laboratory” que se encuentra en el “Instituto de Design” de la Universidade do Minho.
Este proyecto consiste en un estudio de la arcilla y las diferentes técnicas de fabricación que se pueden aplicar a este material. Se estudian técnicas como la extrusión, el moldeo y el corte con hilo. Por último, se propone utilizar estas técnicas para crear un elemento modular de arcilla que pueda utilizarse para el diseño de fachadas y la arquitectura.

Palabras clave: Arcilla, Cerámica, Extrusión, Moldeo, Corte de alambre, Fabricación, Diseño de fachadas.

ABSTRACT

The present investigation was developed within the context of the Design Industry curricular unit, in the second semester of the third year of the Product Design degree at the University of Minho.

This curricular unit aims to bring students closer to the world of work by connecting them through a company and giving them the opportunity to apply what they have learnt throughout their studies. The internship took place at the Advanced Ceramics Laboratory, located at the Institute of Design of the University of Minho.

This project consists of a study of clay and the different manufacturing techniques that can be applied to this material. Techniques such as extrusion, moulding and wire cutting are explored. Finally, a proposal is made to use these techniques to create a modular clay element that can be used for façade design and architecture.

Keywords: Clay, Ceramics, Extrusion, Moulding, Wire cut, Manufacturing, Façade design.

DOSSIER DO PROJETO

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Design and manufacturing
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Universidade do Minho
Escola de Arquitetura, Arte e Design

https://www.eaad.uminho.pt

R. da Ramada, 4810-531 Guimarães
IDEGUI – Instituto de Design de Guimarães
Orientador: Bruno Figueiredo

ACL
Advanced Ceramics Laboratory

https://actech.uminho.pt/
Escola de arquitetura, arte e design
Universidade do Minho
R. de Francos 341, 4800-058 Azurém
Supervisor: Paulo J. S. Cruz

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1. INTRODUCTION

1.1. INTRODUCTION

This document was developed within the context of the Design Industry curricular unit, in the second semester of the third year of the Product Design degree at the University of Minho. This curricular unit aims to bring students closer to the world of work by connecting them through a company and giving them the opportunity to apply what they have learnt throughout their studies.

To carry out this project, the Institute of Design of Guimarães (IDEGUI) was selected, more specifically the Advanced Ceramics Laboratory (ACL), with the guidance of Professor Bruno Figueiredo and the help of Tatiana Campos and João Ribeiro. ACL is a facility which integrates architecture, construction, and technology hub (ACTech Hub) inside the School of Architecture, Art and Design. This laboratory aims to design and manufacture architectural elements created from the additive manufacturing of ceramic materials. The company also works with other materials such as cellulose or concrete.

In the context of this project, it was proposed to work with clay (*Figure 1*) as a modelling material and to use it in the design and manufacture of architectural elements.

In this way, the work plan was established, which consisted of the study of this material, as well as the techniques or new ways of working with it and, finally, the study of shapes in order to design a modular façade element.

Figure 1: Clay. [1]

1.2. PROPOSAL AND GOALS

The initial project proposal is to create a modular element that can be used for the construction of façades or decorative walls with the aim of introducing clay as a construction material and giving relevance to manual work in the industrial context.

Therefore, it is proposed to work with this material in the context of techniques and shape modelling to find multiple design possibilities.

One of the main goals of this project is to work with the material and study two of the most used techniques in its modelling; extrusion and moulding, both combined with wire cutting. Another goal is to find an attractive and easy to reproduce shape in a continuous way by creating a module designing a pattern mesh.

1.3. METHODOLOGY

Phase I: EXPLORATION

Initial phase. Search for references. Contact with the material. Organisation of the project.

Phase II: EXPERIENCE

Preliminary studies of material, technique and shape. Material designs to carry out the preliminary study. Beginning of the dossier.

Phase III: PROPOSAL

Shape studies focused on a possible proposal. Sketching of final proposals. Work on the material dedicated to the final proposal.

Phase IV: PROJECT

Development of the proposal. End of the project. Production of the report and digital material.

1.4. ACL

This project is carried out in ACL (Advanced Ceramics Laboratory) at the Institute of Design of Guimarães (IDEGUI).

Institute of Design of Guimarães is an institution dedicated to research and incorporation of design in product development both for specialised courses and for the promotion of industrial products linked to design. This institute works in coordination with the University of Minho and other research institutions and is considered a centre of expertise in the area of product design.

Advanced Ceramics Laboratory aims to explore and integrate digital additive manufacturing techniques in architectural projects and production processes of ceramic elements in construction.

The advent of ceramic 3D printing brought unprecedented possibilities for the building industry exploring and incorporating components with specific design requirements. It definitively reshaped and expanded the boundaries of what's possible to achieve with masonry construction and opened new domains, with multiple angles of study and experimentation and with a huge industrial potential. Plenty of projects have been developed in this context. (*Figures 2-3*)

This project explores the process of extrusion, a crucial process in ceramic 3D printing. It also works, in parallel and thanks to the company, on the design of dies for the extruder machine directly connected to 3D modelling and filament 3D printing. *[2]*


Figure 2: ACL project. Hybrid columns. [3]


Figure 3: ACL project. S-brick wall. [4]

2. STATE OF THE ART

2.1. CLAY

The material to be used in this project will be clay, so the following study of it has been made.

Clay is a type of phyllosilicate mineral (*Figure 4*). It comes from the three main groups of rocks: igneous, metamorphic, and sedimentary, weathered or altered by water and heat, and is composed of feldspars and hydrated aluminium silicates. The purest is white in colour, but it is also easy to find brown, red, or copper-coloured if they contain other substances.

Figure 4: Clay in its natural state. [5]

It is a type of decomposed sedimentary rock. It contains aggregates of hydrated aluminium silicates, which come from metamorphic, sedimentary, and igneous rocks that were weathered and contained feldspar inside. Its chemical formula is Al2O3 - 2SiO2 - 2H2O.

It is considered a colloid, because it contains small, smooth-surfaced particles with a diameter much smaller than 0.0039 mm. In addition, it can be composed of non-mineral particles known as phytoliths. *[6]*

2.1.1. CHARACTERISTICS

The main physical characteristics *[7]* that were interesting to our project are:

- It has a smooth surface and small particle size of at least 0.002 millimetres in diameter.
- Its particles can only be seen with a microscope.
- It is considered a colloid, a group of very fine solid particles that stick together.
- It can form clots or a pasty fluid. If mixed with water, it becomes plastic.
- It is not filterable.
- If heated, it acquires sonority and resistance.

2.1.2. PROPERTIES

The main properties *[7]* of clay are:

Plasticity: By adding water, it can be mouldable and take on any shape.

Shrinkage: When the water we add evaporates during drying, the paste shrinks.

Refractoriness: It can withstand different temperatures without changing its properties. Each type of clay has its own firing time to acquire a certain resistance.

Porosity: This property varies according to the type of clay and its consistency when it has undergone a drying and firing process.

Colour: It can have different colours due to its mineral content, especially calcium carbonate and iron oxide.

2.1.3. USES

Clay was used in the past to make pots, vessels, tombs, coffins, and other items. It is also used to construct buildings, as it is useful for making bricks and adobe bricks.

When it is moistened, it can be moulded and if left to dry in the sun, it will harden. But if we subject it to the heat of a kiln, it will become more rigid and become ceramic.

Today it is used to make pots, vases, bricks, ocarinas, works of art and plates (*Figure 5*). It is also very useful in the production of cement, porcelain, paper, filter elements and earthenware. *[7]*

Figure 5: Uses of clay. [8]

2.1.4. TYPES

BRICK CLAY (*Figure 6***)**

Contains many impurities. When fired, it has yellowish or reddish tones, depending on the amount of iron oxide involved in its composition. It is used in utilitarian ceramics (pots, jars, etc.) Firing temperature: 850-1.000º Firing temperature: 850-1.000º.

Figure 6: Brick clay. [9]

POTTER'S CLAY (*Figure 7***)**

Also called red clay and used in pottery and modelling. When fired, it has a light reddish or brownish colour. Because of the great fineness that can be achieved with a good finish, it is used unglazed for decoration. It is also ideal for the potter's wheel. Firing temperature: 900-1.050º. Above these degrees it deforms.

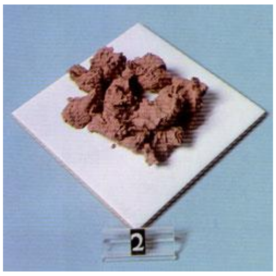

Figure 7: Potter's clay. [9]

STONEWARE CLAY (*Figure 8***)**

It is a clay with a high feldspar content. When fired, it has great plasticity and minimal absorption, presenting light, grey or cream tones. It is used on the wheel for high-temperature glazes. Firing temperature: over 1.000º.

Figure 8: Stoneware clay. [9]

BALL CLAYS (*Figure 9***)**

Due to the large amount of organic matter, it contains, it has a dark or grey colour when raw, which becomes lighter when fired. It belongs to the group of fatty clays, and due to its great capacity for shrinkage, it is not used alone. It is ideal for hand modelling.

Figure 9: Ball clays. [9]

CAOLIN (*Figure 10***)**

It is the purest clay (primary) and when washed it produces very white pastes. Not very plastic and very refractory, it is never used alone but mixed with other clays. Due to its whiteness, it is the basis of porcelain. Firing temperature: between 1.250º and 1.450º, depending on whether it is soft or hard porcelain.

Figure 10: Caolin. [9]

REFRACTORY CLAY (*Figure 11*)

Very resistant to temperature, it melts above 1.500º, so it is used for the manufacture of bricks for refractory kilns and for modelling murals. This clay has many impurities, so when applied to murals mixed with chamotte (the same clay ground and fired) it produces different and interesting textures.

Figure 11: Refractory clay. [9]

BENTONITE (*Figure 12*)

Clay derived from volcanic ashes; it is very plastic because its molecules are very small. It is used mixed in earthenware or porcelain pastes and its proportion should not be greater than 3%, as due to the large amount of iron it contains and its high concentration it would cause cracks in the pieces. *[9]*

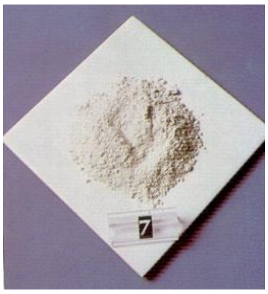

Figure 12: Bentonite. [9]

2.2. CLAY MODELLING

2.2.1. TECHNIQUES AND TOOLS

1. Pinching: This technique involves shaping the clay by pinching it between the thumb and fingers. Pinching is often used to create small, hollow forms like bowls, cups, and pots. It is an excellent technique to develop a feel for the clay and control over its shape. (*Figure 13*)

Figure 13: Pinching. [10]

2. Coiling: Coiling involves rolling out long, thin ropes of clay and then stacking them to create a form. The coils can be left visible for a textured effect, or they can be smoothed and blended to create a seamless surface. This technique is suitable for building larger, more complex shapes, such as vases or sculptures. (*Figure 14*)

Figure 14: Coiling. [11]

3. Slab building: Slab building involves rolling out flat, even sheets of clay and then cutting and assembling them into the desired shape. Slabs can be used to create boxes, cylinders, or more complex structures. This technique is ideal for creating geometric forms and requires careful attention to detail to ensure the edges and corners are neat and aligned. (*Figure 15*)

Figure 15: Slab building. [12]

4. Sculpting: Sculpting is the process of shaping and carving the clay by hand or using various tools. This technique allows for a high degree of detail and is commonly used for creating figurines, busts, and other intricate forms. Sculpting requires patience, practice, and a keen eye for proportions and form. (*Figure 16*)


Figure 16: Sculpting. [13]

5. Throwing: Throwing is the process of shaping clay on a potter's wheel. As the wheel spins, the artist uses their hands to manipulate and shape the clay into the desired form. Throwing is often used to create symmetrical, round objects like bowls, plates, and vases. This technique requires skill and coordination, as well as a thorough understanding of the properties of the clay being used. (*Figure 17*)


Figure 17: Throwing. [14]

6. Extruding: Extruding involves forcing the clay through a shaped opening or die, creating a continuous form with a consistent cross-section. This technique is often used for creating handles, borders, or decorative elements that can be attached to other clay forms. Extruders come in various shapes and sizes, allowing for a wide range of possibilities. (*Figure 18*)


Figure 18: Extruding. [15]

7. Press moulding: Press moulding involves pressing clay into a pre-made mould, either by hand or using a machine. This technique is useful for creating multiple identical pieces or for reproducing intricate details. Press moulding is commonly used in mass production or for creating intricate relief designs. (*Figure 19*)


Figure 19: Press moulding first example. [16]

8. Slip casting: Slip casting is a technique where liquid clay, or slip, is poured into a plaster mould. The plaster absorbs the moisture from the slip, leaving a layer of solid clay adhering to the mould's surface. Once the desired thickness is achieved, the excess slip is poured out, and the clay is left to dry before being removed from the mould. This technique is popular for creating complex shapes and delicate, thin-walled forms that are difficult to achieve with other methods. (*Figure 20*) *[18]*


Figure 20: Slip casting. [17]

2.2.2. EXTRUSION AND MOULDING

Among the techniques mentioned in the previous section, extrusion and moulding are the two techniques on which this project focuses.

As mentioned, extruding involves forcing the clay through a shaped opening or die, creating a continuous form with a consistent cross-section.

This technique offers the facility to reproduce the selected profile through the die and provides an interesting continuous form to work with. (*Figure 21*)

In this process, an extruder machine (*Figure 23*) is normally used, anchored to the wall or to a table. This machine usually consists of a hollow cylindrical tube. On one side, the die that will give us the shape we are looking for is placed, and on the other side the paste is introduced. On this same side, the piston is introduced, in order to press the clay, compressing it until it comes out of the other side of the cylinder.

The machine described could be a manual machine, but there are also computer numerical control extruders, programmed to perform the action of extruding the material.

In the case of using a mould to model the clay, we base the technique on depositing the material in a mould with the shape we want to achieve.

The material the mould is made of is important, as it has to facilitate the task of separating the piece from the mould. (*Figure 22*)

The technique of mould pressing is commonly used, which consists of pressing the paste into the shape of the mould with the hands or a tool.

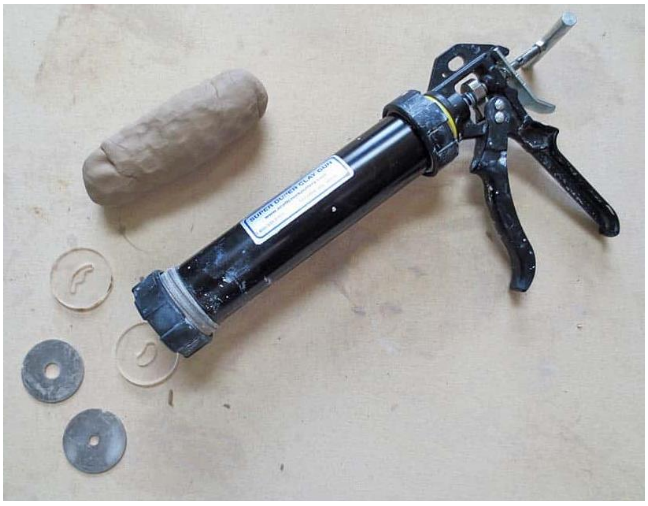

Figure 23: Hand extruder with dies. [19]

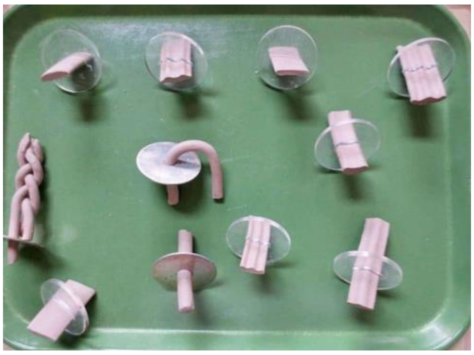

Figure 21: Clay tests with dies for handles. [19]

Figure 22: Press moulding second example. [20]

2.2.3. WIRE CUTTING

This is a technique for making clean cuts in clay. This versatile tool can be used to cut pieces of clay from larger blocks, remove pots from the wheel and even out edges and angles. Wire cutters come in various lengths and gauges and have different types of handles. Thicker wires tend to be stronger and last longer, while thinner wires offer a cleaner cut but are more prone to fray or break over time. And while traditional wire cutters usually have wooden handles, there is a wide variety of handle materials and designs on the market, such as plastic or silicone handles. (*Figures 24 and 26*)

Figure 24: Wire cutting without handles. [21]

This technique can be performed either manually, as mentioned above, or with a machine. Wire-cutting robots can be very useful as you can program the path you want the wire to take through the workpiece.

Figure 25: Wires with different handles. [22]

It is also important to consider the thickness of the wire to achieve a cleaner cut. The wire should be of steel and of sufficient length to be able to cut larger quantities.

The shape of the handle is also decisive, because depending on the handle shape, different forces must be applied, and this can be very useful when it is difficult to cut a certain workpiece. (*Figure 25*)

Figure 26: Wire cutting with wooden handles. [23]

2.3. OTHER PROJECTS

A search has been carried out for certain existing projects related to clay or ceramic modelling in architecture that are of interest for the development of this project.

2.3.1. COOLANT BEEHIVE

CoolAnt Beehive (*Figure 27*) was set up at India International Science Festival, Lucknow in 2018. This installation had a footfall of over half a million people during the festival.

New Delhi-based company has developed the CoolAnt Beehive, which is an outdoor and semi-outdoor cooling solution. Based on the idea of earthen pots cooling water through evaporation, the Beehive uses the same principle in reverse. It works by soaking hundreds of stacked earthen pots in water and letting the air pass through.

Figure 27: Outdoor coolant beehive in circular shape. [24]

Made of terracotta provided by local potters, the CoolAnt Beehive also generates employment in this line of craft. By making sure that their potters' stories reach clients, they generate inquiries for the pottery community and engage people in the craft's art and evolution.

The beehives can be installed in public plazas, markets, government buildings, schools, shopping centres, hospitals and more. And, in winter, it can serve a double function as an air purifier with auxiliary ferns and moss plants. (*Figure 28*)

What's more, the designers behind the Beehive are looking to transform the design into a solution for low-income households, who often suffer during high temperatures. That's why they're working on a simpler, less expensive version. *[24] [25]*

Figure 28: Indoor coolant beehive in vertical position. [24]

2.3.2. ITHACUT: ROBOTIC WIRE CUTTING CLAY

This was a project carried out by the IAAC (Institute for Advanced Architecture of Catalonia) at the MRAC (Master in Robotics and Advanced Constructions) in the 2020-2021 academic year.

This project is exploring a system which could make exhaustive use of the fabrication equipment, while efficiently maximizing the production process and final element. It pursues an assembly type made by clay that could be flexible as an exterior partition wall or rain / sunscreen for a building envelope.

The proposal is consisted of three rows of uniquely perforated rectangular profiles. The perforation of the profile's changes depending on where they are placed. The exterior units have larger holes, contrarily to the ones that are placed in the interior row, which have smaller holes. (*Figure 29*)

The first aim of the project was to create an air screening wall. The initial idea was to have two exterior rows that help the air flow through the wall and one row in the middle which will be used as a water container. (*Figures 30 and 31*) *[26]*

Figure 29: Designed modular elements. [26]

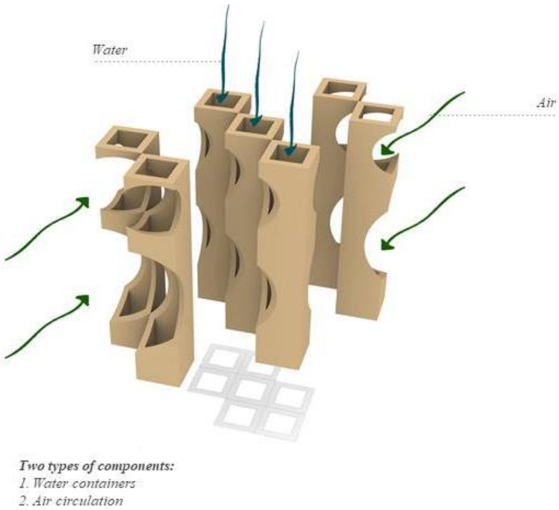

Figure 30: Function description of the modular elements. [26]

Figure 31: Virtual representation of the project outside. [26]

2.3.3. A FACTORY AS IT MIGHT BE

A Factory As It Might Be was an architectural installation at A/D/O by Assemble, Granby Workshop, Will Shannon & collaborators. The installation was set up as a model factory, equipped with clay and an industrial extruder.


Figure 32: Extrusion of clay cylinders. [27]

The project explored the idea of itinerant production -exporting the experimental production approach of Granby Workshop from Liverpool to New York. The Factory was equipped with an industrial extruder and over the course of two months a range of experimental, extruded products were developed by the group working in residence at A/D/O. (*Figures 32 and 33*)


Figure 33: Workshop of the project. [27]

The factory's first products were designed to add to the structure of the building itself. A cladding of ceramic shingles was made for the façade, alongside planters, dinnerware, and door handles, creating a richly decorated building that was part workspace, part display space. (*Figures 34 and 35*)

The clay extruder pushes material through holes in metal plates to create different shapes. Over the course of its three-month stay, the factory will produce all types of products, from planters and permanent tiles for A/D/O's courtyard to dinnerware for the restaurant. *[27] [28]*


Figure 34: Tiles extrusion process. [27]


Figure 35: Clay designed façade for 'A factory as it might be.' [27]

3. PREVIOUS STUDIES

3.1. STUDY OF THE MATERIAL

The study of the material consists of preparing it, make experiments mixing with water and observing its plasticity.

3.1.1. CLAY IN BLOCK

First, we start working with the clay in block form and study how it behaves with different amounts of water (*Figure 36*). We will also make wire cuts in small, extruded tubes to study the ease of cutting in different situations. Finally, these will be subjected to a plasticity study. (*Figure 38*)

The clay used for this test is of the VICAR brand and is of the GRES-130-MP type.

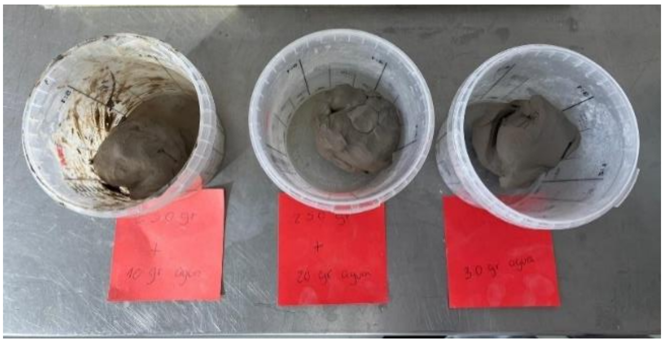

Figure 36: Clay block tests: mix clay with water.

Clay block tests: mix clay with water.

1- 250 gr of clay, 0 gr of water.

2- 250 gr of clay, 10 gr of water.

3- 250 gr of clay, 20 gr of water.

4- 250 gr of clay, 30 gr of water.

Once the paste is ready, we extrude it to form small clay tubes (*Figure 37*).

Figure 37: Tool for extruding small tubes.

From the paste obtained we make three tubes. We cut two of them with wire to check the ease of cutting. The last one is subjected to a plasticity study by means of an external load, obtaining the difference in size that the tube experiences when it is crushed. (*Figures 39-42*)

Clay block tests: plasticity. Initially, the tube measures 4 cm.

1- With 0 g, it is reduced to 3.5 cm.

2- With 10 g, it is reduced to 2.5 cm.

3- With 20 g, it is reduced to 2 cm.

4- With 30 gr, it is reduced to 1.5 cm.

Figure 38: Apparatus for performing the plasticity study.

Conclusion: The clay that has not been mixed with water is the best to work with in terms of cutting with wire. It has less tendency to deform and the cutting with wire is the easiest and most precise. However, extrusion is more complicated, being easier with an intermediate amount of water.

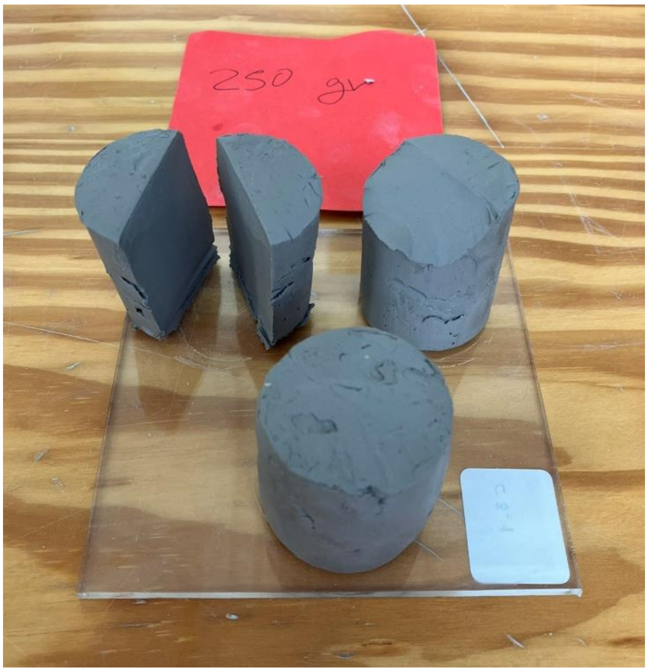

Figure 39: Test with 250 grams of block clay.

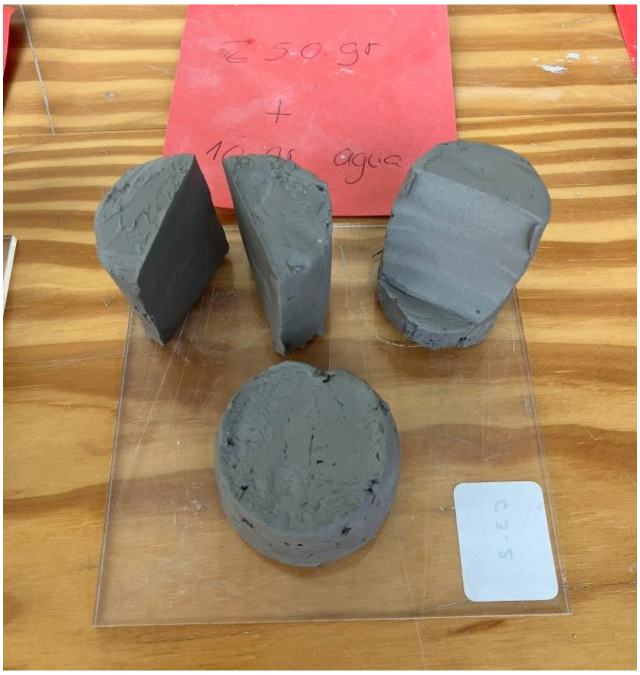

Figure 40: Test with 250 grams of block clay mixed with 10 grams of water.

Figure 41: Test with 250 grams of block clay mixed with 20 grams of water.

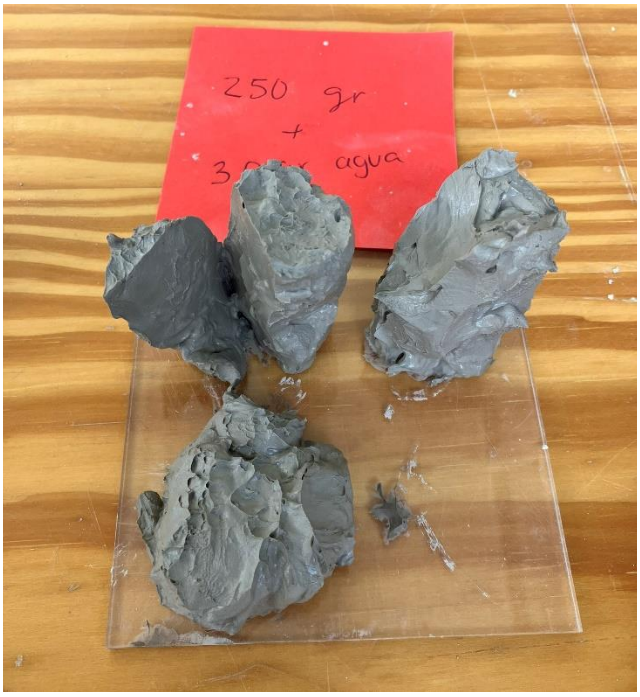

Figure 42: Test with 250 grams of block clay mixed with 30 grams of water.

3.1.2. CLAY IN POWDER

We carry out the same study but in this case with powdered clay. We mix it with water (*Figures 43-45*) to obtain the paste, extrude some tubes and proceed with them in the same way. (*Figures 46-48*)

The powdered clay used is of the Hagemeister brand, type Bergheim GT NF 275.

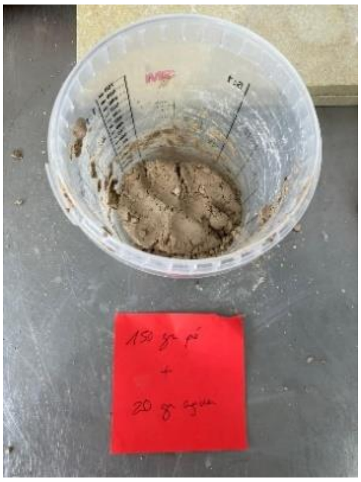

Figure 43: Mixture in vase of 150 grams of powder clay with 20 grams of water.

Figure 44: Mixture in vase of 150 grams of powder clay with 30 grams of water.

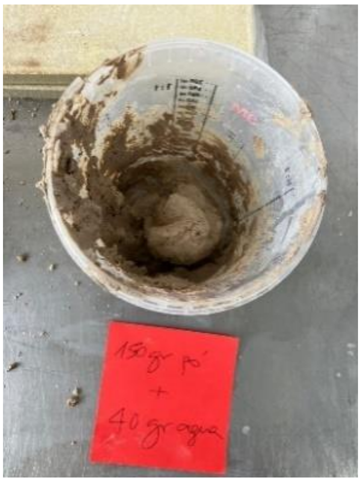

Figure 45: Mixture in vase of 150 grams of powder clay with 40 grams of water.

Tests with powdered clay: mix clay with water.

1- 150 gr of clay, 20 gr of water.

2- 150 g of clay, 30 g of water.

3- 150 g clay, 40 g water.

Tests with powdered clay: plasticity. Initially, the tube measures 4 cm.

1- With 20 g, it is reduced to 3 cm.

2- With 30 g, it is reduced to 2.7 cm.

3- With 40 gr, it is reduced to 1.7 cm.

Conclusion: The paste that worked best was, as last time, the one with the least amount of water. We tried using even less water, but the paste did not settle, and the powder remained loose in this way. As in the previous test, the paste extruded better with more water, but was cut better with less.

Figure 46: Test with 150 grams of powder clay with 20 grams of water.

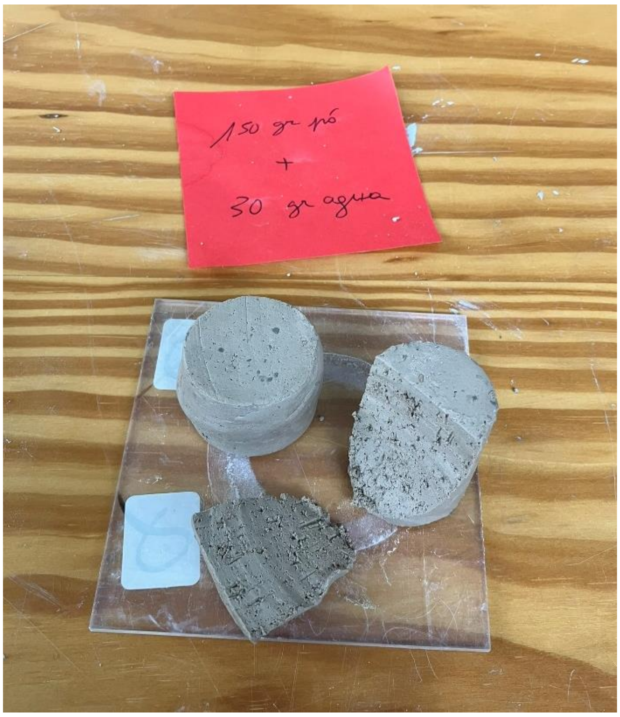

Figure 47: Test with 150 grams of powder clay with 30 grams of water.

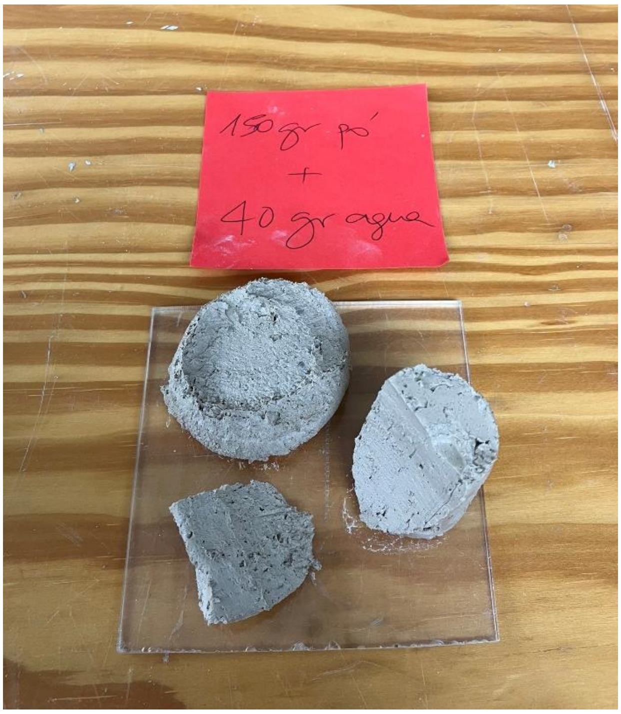

Figure 48: Test with 150 grams of powder clay with 40 grams of water.

3.2. STUDY OF THE TECHNIQUE

Once we are more familiar with the material we proceed to explore different clay modelling techniques.

3.2.1. EXTRUSION MODELLING

With the clay in block form, we carried out extrusion tests with a wall extruder (*Figure 49*) and dies that extrude different shapes.

Figure 49: Clay extruder.

This wall extruder has a removable part (*Figure 50*) which allows you to insert different dies that have the shape you want to extrude.

The operation of this tool is relatively simple. From testing with water, we conclude that the clay extrudes better with more water. Thanks to this, we can find the proportion between the quantities of water and material and introduce it into our extruder and make clay cylinders with different diameters.

Figure 50: Detachable part of the extruder to hold the dies.

A first interaction with the extrusion is shown below (*Figure 51*) in which the clay was used in block form without being mixed with water.

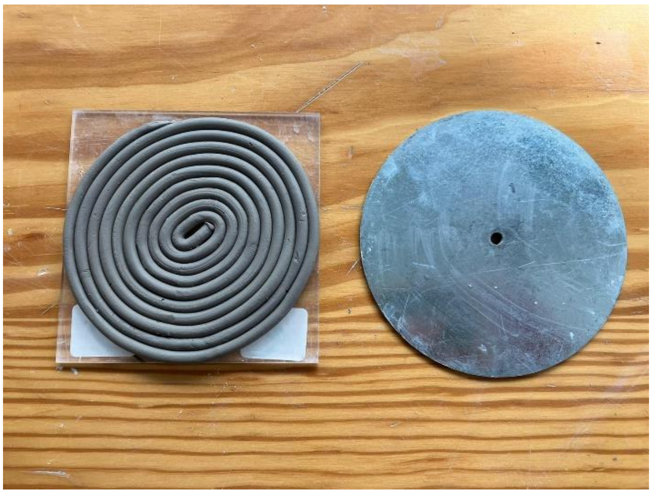

Figure 51: Extrusion test with block clay.

Secondly, another test (*Figure 52*) with a different die (*Figure 53*) is shown in which we observe that different shapes are extruded.

Figure 52: Extrusion tests with multi-hole die.

Figure 53: Multi-hole die.

3.2.1.1. PROBLEMS OBSERVED WHEN EXTRUDING

The first problem is that, if the paste created has a small amount of water, it extrudes worse, and therefore sticks in spaces that cannot extrude it well. (*Figure 54*)

The solution would be to create the perfect water/clay proportion.

Figure 54: Clay stuck in the die.

The second problem is that, if the die that we use does not fit properly, there will be a gap between it and the extruder through which the clay can come out once we start to extrude. (*Figure 55*)

The solution to this would be to make sure that the parts fit together as well as possible or, failing that, to cover the gap with adhesive tape to prevent the clay from coming out through it. (*Figure 56*)

Figure 55: Clay coming out from the extruder through an unwanted gap.

Figure 56: Solution so that the clay does not come out in unwanted places.

The third and last problem would be if we applied too much pressure with the piston, we could be ending breaking the die. (*Figure 57*)

To solve this problem, the ideal solution would be to extrude carefully and measure the distance between the piston and the die. Another solution would be to make sure that the parts of the die are well designed and can withstand the pressure.

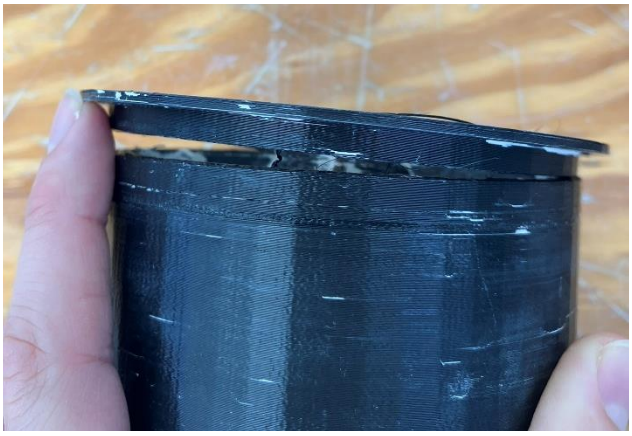

Figure 57: Broken die.

3.2.2. MOULD MODELLING

In order to achieve new shapes with the clay, a mould has been created in which the clay can be introduced. (*Figure 59*)

In this case, a square-shaped mould was made. The mould is made of wood. The largest block that can come out of the mould is 15x20x4 cm.

To introduce the clay, we use a spray can to apply water and to be able to mould the material that we add to the inside of the mould.

Once we have filled the mould, we can take out the shape and work with it. (*Figure 58*)

Figure 58: Clay block made with wooden mould.

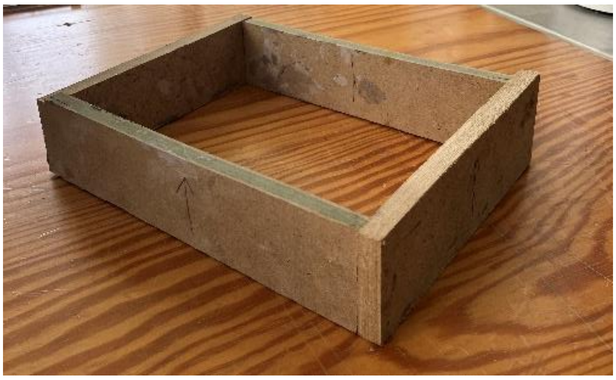

Figure 59: Wooden mould.

3.2.3. WIRE CUT

Another technique studied is wire cutting. With this tool I have practised making cuts as precise as possible and in different quantities to be able to cut other types of shapes later on.

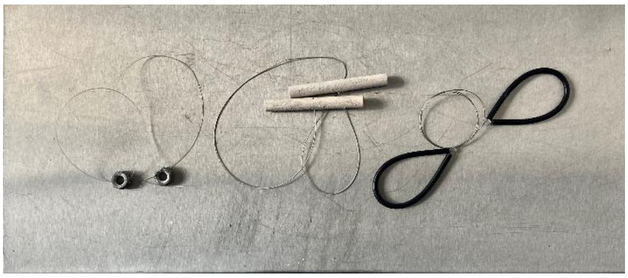

Figure 60: Wires for cutting clay.

As mentioned above, there are several types of wires depending on the handles they have. In the case of the first wire we used, it is tied at its ends to two screws that make it easier to hold the wire while cutting. The second one we used was the one with wooden handles, which, being longer than the screws, allows a better hold and makes it easier to apply more force when cutting. Finally, we used the wire with silicone handles, with gaps that allows you to insert your hands to better pull the wire when cutting large pieces. (*Figure 60*)

To practice this type of cutting we have tried cutting a block of clay into different shapes. When cutting large pieces, we tried to make the cut as precise as possible because when you apply more force this task becomes more complicated.

This technique is also interesting because, in the case of block clay, it is sold in large blocks that you need to cut to work with. (*Figure 61*)

Figure 61: Pieces of clay cut with wire.

The following images show the use of wire cutting to perform this action. (*Figure 62-64*)

Figure 62: Big block of clay with cut made.

Figure 63: Big block of clay with small piece separated from it by wire cutting.

Figure 64: Piece of clay wire cut out from the big block.

3.3. STUDY OF THE SHAPE

3.3.1. WIRE CUTTING PROFILE SHAPES

By further studying the shapes that can be made with the wire, we have designed a way for the wire to make a precise cut with the help of a piece that serves as a guide for its path.

This new technique consists of wooden templates that have a curved shape (*Figure 65*). These patterns, which can have different designs, are placed on the sides of the block or piece of clay and fixed to it. In this way the piece is held in place and allows us to pass the wire following the desired shape previously designed. (*Figures 66 and 67*)

Figure 65: Wooden templates for curved shapes.

Figure 66: Wooden templates with grips on clay block.

Figure 67: Clay block wire cut thanks to the wooden templates.

In this way we can also combine the templates and make a different shape on each side, resulting in an interesting and irregular shape. (*Figures 68-70*)

Figure 68: Clay block cut with wire seen from above.

Figure 69: Clay block profile with shape number 1.

Figure 70: Clay block profile with shape number 2.

4. DEVELOPMENT OF THE PROJECT

4.1. EXTRUSION AND WIRE CUTTING PROCESS

4.2. MOULDING AND WIRE CUTTING PROCESS

4.1. EXTRUSION AND WIRE CUTTING PROCESS

4.1.1. DIES DESIGN AND USE PROCESS

In order to continue with the study of the shape, although this time more focused on the final proposal of extrusion, some dies have been designed for the extruder that give shape to different designs.

The process of designing these parts from the beginning until the final clay piece is obtained with its specific shape is explained in the steps below.

The reason for making this die design is due to the models we have in the laboratory have simpler shapes with less variety and our aim is to study the shapes that can be modelled in the material as a whole.

STEP 1: STUDY OF THE MACHINE

The first step is based on carrying out a measurement study to be able to design the exact die and fit it in the hole of the machine designed for it (*Figure 71*). We measure the diameter of the hole and the maximum diameter that the die can have.

Figure 71: Clay extruder.

STEP 2: SOFTWARE IMPLEMENTATION

Thanks to the design proposal from the advisor, we can get an idea of how the die is going to look like and we can proceed to model it with the Solid Works tool. This design proposal is based on other existing commercially available dies that are suitable for this type of machine.

We make a series of sketches that show us what the component is going to look like and what measurements it is going to have. In this step it is important to think about how the measurements relate to each other and the size of the piece profile that we are going to extrude.

Now, we carry out the sketching in Solid Works, the computer design software for modelling components and assemblies in 3D and 2D drawings. In this way we design the basis of what our die is going to be and the measurements it is going to have. We continue with the modelling of these sketches, so that the component is defined in 3D. We also check that all the measurements are correct and that the parts of the component are well designed. (*Figure 72*)

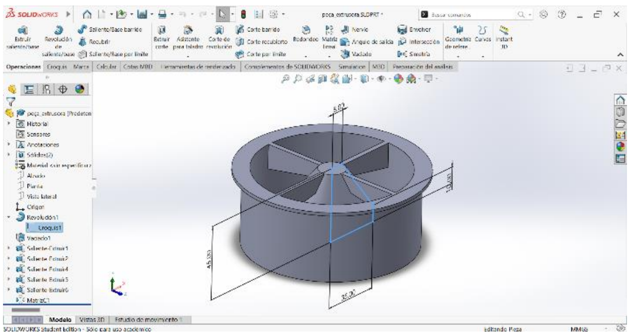

Figure 72: Solid Works interface designing the die.

STEP 3: 3D PRINTING OF THE DIE

Next, we proceed to bring the die to reality using the 3D printer (*Figure 73*). The material used is PLA with a neutral colour filament as the colour is not relevant. We send the model in STL format to the laboratory where the die will be printed.

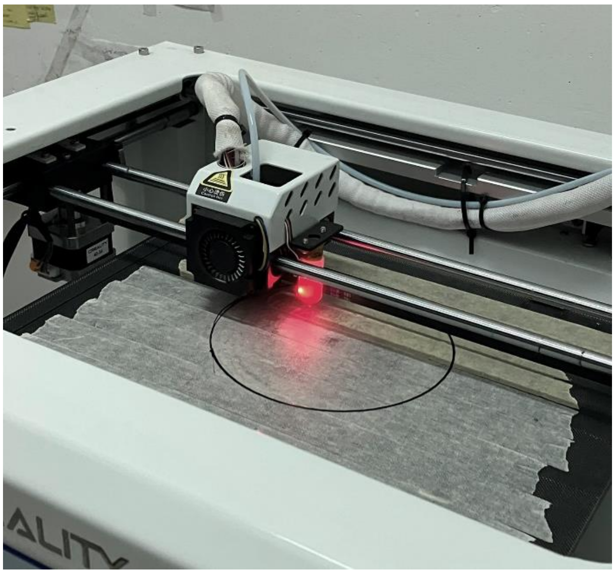

Figure 73: 3D printer starting the printing of the piece.

STEP 4: PLACE IN THE MACHINE

Once the die has been obtained (*Figure 75*), we check that it fits in the machine, and we make sure that it is well fastened to avoid holes through which the extruded clay could come out later. (*Figure 74*)

Figure 74: Die placed in extruder.

Figure 75: Die made with 3D printing.

STEP 5: CREATING THE CLAY

Next, we prepare the paste that we are going to introduce into the machine (*Figure 76*). Thanks to the previous studies we can know the exact proportion of clay and water so that the material extrudes better, and we can play with these values testing with the die to find the perfect quantity so that the machine extrudes as we wish.

Figure 74: Clay paste ready to put into the extruder.

STEP 6: EXTRUSION OF THE PASTE

Once we have obtained the quantity we want, which will vary depending on the piece we want to obtain, we proceed to press with the extruder piston so that the desired shape comes out (*Figure 77*).

Figure 75: Extruded clay coming out of the extruder.

STEP 7: PREPARATION FOR CUTTING

Once the extruded paste starts to come out on the other side, that is to say, with the shape that the die is giving it, it is interesting to place a plastic base or other material that sticks to the end of the clay piece (*Figure 78*). This is important because, as well as giving uniformity to one side of the work piece, it will make it easier to pick it up and transport it when we finish extruding and cut it with the wire.

Figure 76: Plastic piece stuck to one side of the extruded piece to facilitate removal.

STEP 8: CHECK DEPTH

The piston that presses the clay has a maximum distance that we must control while extruding. This is because, if we overdo it, we can break the die and it is also important to know when the material is finished, and we cannot extrude any more. For this, we use an object to measure how much space we have left. In this case, we use a wooden stick with a mark that indicates our limit. (*Figure 79*)

Figure 77: Testing depth with wooden stick.

STEP 9: CUTTING THE EXTRUDED COMPONENT

In this last step, we take care of cutting our work piece that has come out wherever we want to separate it from the machine. With one hand we make use of the cutting wire and with the other hand we hold the plastic base that we put previously to be able to take the piece easily (*Figure 80*). Once this is finished, all that remains is to remove the die and clean the machine, in this way we can use it again with another die and continue our work.

Figure 78: Holding the piece before cutting.

It should be noted that this process is a continuous process, in which we can always continue designing new dies with which we can obtain different shapes and designs. Once this process is finished, we proceed to go back to the beginning and design new parts, repeating the same steps and obtaining different results.

4.1.2. TYPES OF DIES

Once we have managed to extrude the paste with a die made by us, we proceed to the realisation of several dies with different designs that offer us a variety of shapes.

Below are the two collections of dies according to the shape they extrude.

4.1.2.1. SHAPES COLLECTION

In this collection we find 3 dies with designs of shapes that will allow us to create cylinders or prisms. In addition, they have a significant feature, which is that they allow us to extrude hollow shapes.

As we have already mentioned, the extruder is a cylindrical metal tube, so the die that will go into it must also be cylindrical on the outside. It is then its inner geometry that will allow us to create different pieces. Thanks to this inner geometry, the die allows us to create hollow parts with the shape we want. This inner part is connected to the outer cylinder by means of ribs. The paste enters the upper part through the ribs and goes down the die until it comes out on the other side with the shape of the profile we have designed.

In this case, we have designed three profiles: circular, triangular and square. The reason for making these three profiles is very simple. By using simple shapes, it allows us to combine them later and cut them easily with the wire.

In the following images (*Figures 81-86*) you can see what these dies look like on the top and inside.

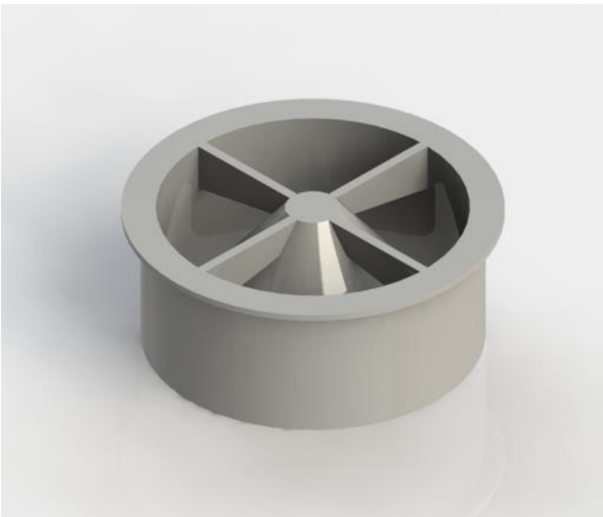

Figure 81: Isometric view of cylinder die.

Figure 82: Bottom view of cylinder die.

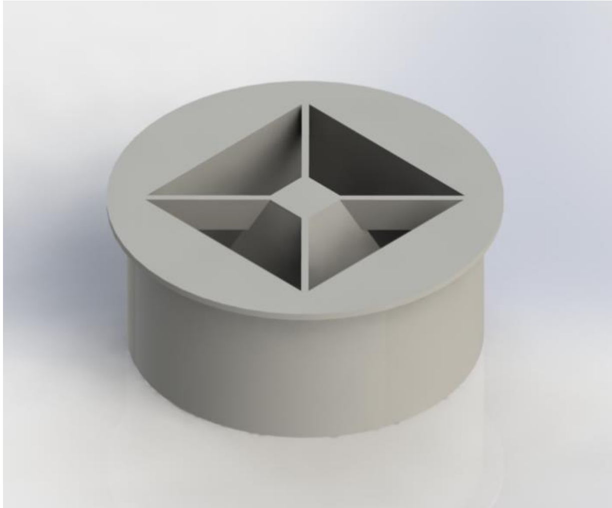

Figure 79: Isometric view of square die.

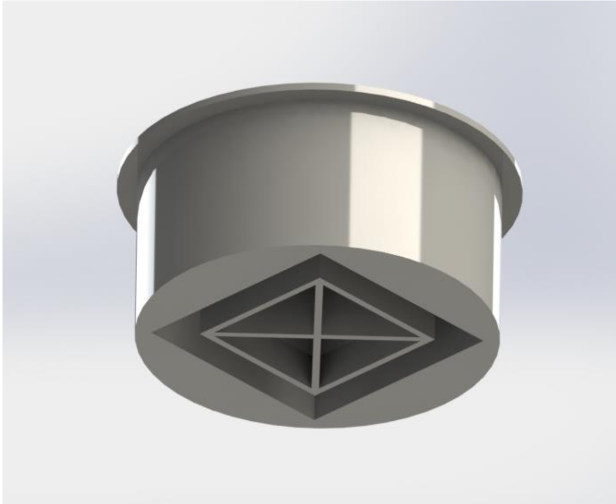

Figure 80: Bottom view of square die.

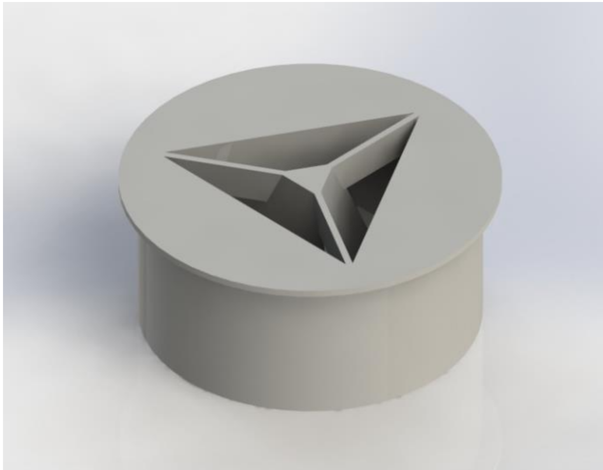

Figure 81: Isometric view of triangular die.

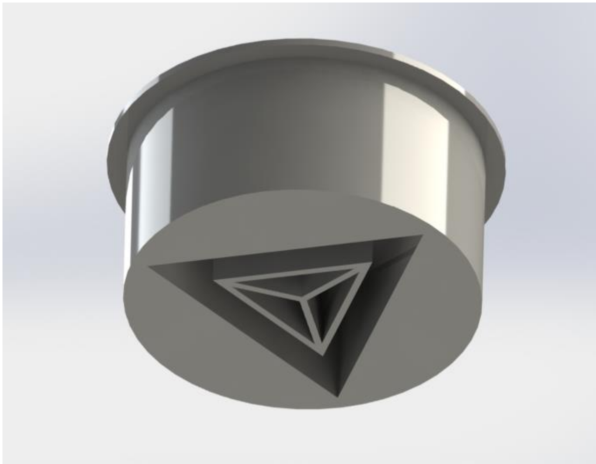

Figure 82: Bottom view of triangular die.

4.1.2.2. LETTERS COLLECTION

In this collection we find three dies with designs of shapes that will allow us to create an extruded profile with the shape of a letter.

Unlike the previous ones, these do not form hollow parts but solid parts. In addition, a different geometry has been designed to connect the shape of the letter with the cylindrical shape of the die to make it easier for the clay to flow through the piece.

In this case, we have designed three letter profiles: E, H, U. The reason for making these two last profiles is because they are often used for the construction of beams.

In the following images (*Figures 87-92*) you can see what these dies look like on the top and bottom.

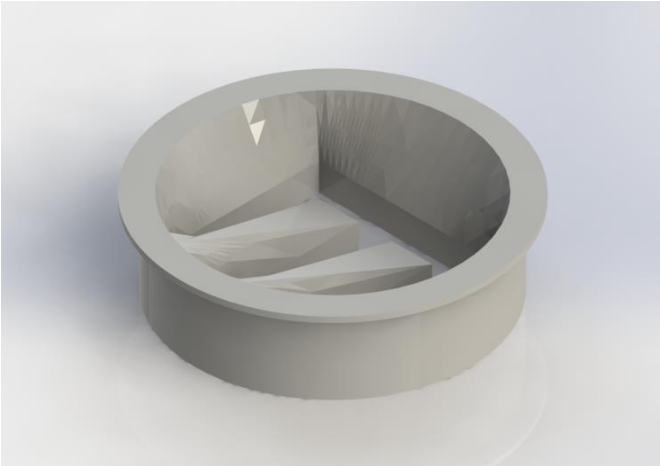
Figure 83: Isometric view of ‘E’ die.


Figure 84: Bottom view of ‘E’ die.

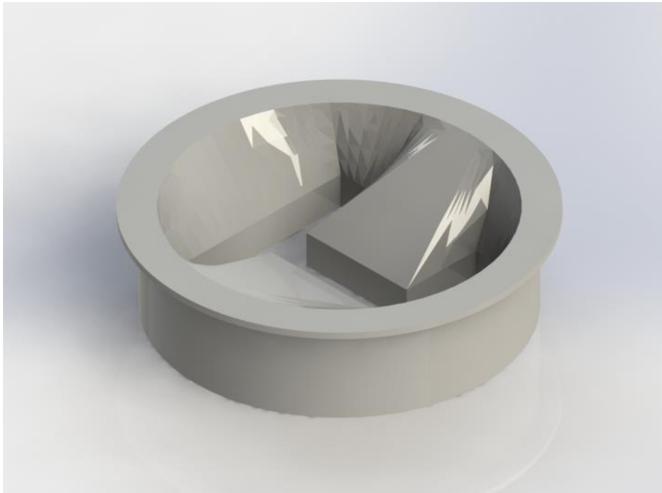
Figure 85: Isometric view of ‘H’ die.


Figure 86: Bottom view of ‘H’ die.

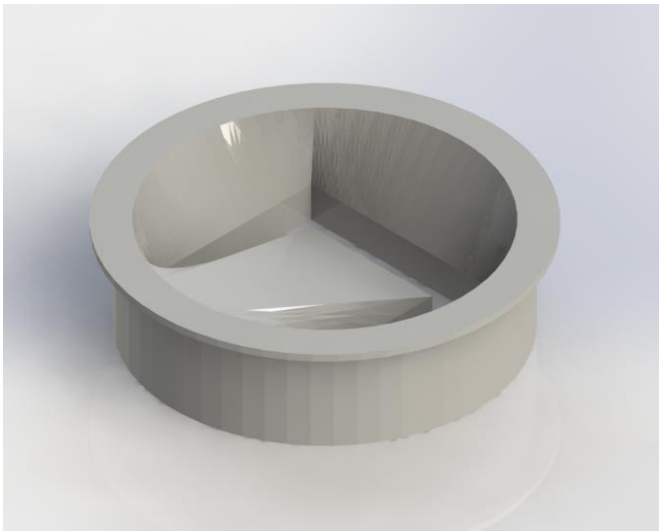
Figure 87: Isometric view of ‘U’ die.


Figure 88: Bottom view of ‘U’ die.

4.1.3. TESTS

The use of these dies in the wall extruder is shown in the following pictures. (*Figures 93-101*)

Figure 89: Cylinder die tests.

Figure 90: Cylinder die tests.

Figure 91: Square die tests.

Figure 92: Square die tests.

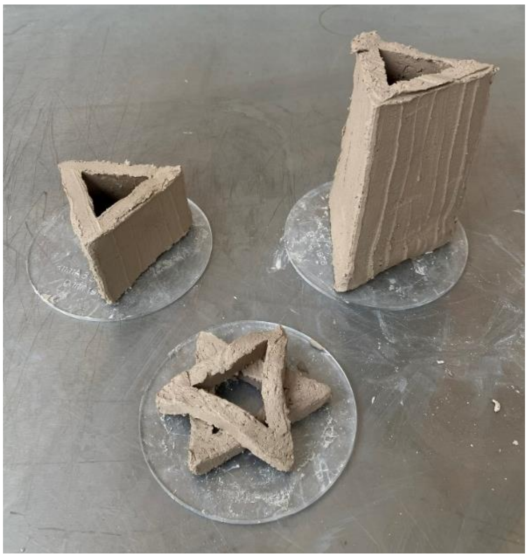

Figure 93: Triangular die tests.

It can be noted that some tests (*Figure 94*) show deformities. In this case it is due to the excessive use of water in the creation of the paste.

Figure 98: 'H' die test.

Figure 99: 'H' die test.

Figure 94: 'E' die test.

Figure 95: 'U' die test.

4.1.4. DRAWINGS AND MEASUREMENTS

Drawings and measurements of the dies designed are presented on Annex 1.

4.2. MOULDING AND WIRE CUTTING PROCESS

In previous studies, the shape was studied through moulding. Also, the block formed from the mould was cut using a series of wooden templates that served as a guide for the wire.

In order to continue with the study of this technique, and to be able to apply it to the design of façades, a moulding and wire-cutting kit has been designed to manufacture a clay block that can be used as a repeating element.

4.2.1. KIT DESIGN AND USE PROCESS

When starting to design the moulding kit, it was realised that the material previously used, wood, was not the most suitable. (*Figure 102*)

The mould created from this material was difficult to transport and clean. In addition, it was difficult to separate the mould from it in order to work with it. It was also found that, as the mould and the templates were two different elements, it was difficult to use both, and other tools were needed to hold the block of clay so that it would not move while it was being cut.

It was concluded that it was necessary to design a kit that would try to combine the mould with the shape templates, and that these could also be combined with a base to fix the clay block. It was also important to choose a lightweight, easy to clean and low-cost material.

Figure 96: Wet and uncleaned wooden mould.

It was then agreed that the material to be used would be acrylic boards of different thicknesses. A series of pieces were designed that fit together to form the space that the clay would occupy. These pieces can be disassembled so that, once the block has been moulded, the shape templates, also made of acrylic, can be placed and the block can be cut with the wire. This process will be explained in more detail below.

STEP 1: DESIGN OF THE PIECES

The pieces were designed using Adobe Illustrator. The measurements they were going to have to fit together were established, as well as the different shapes they would have.

STEP 2: CUTTING OF THE PIECES

The cutting of the pieces was carried out with a laser cutter (*Figure 103*). Previously, it was defined how many pieces of each type there were going to be. In this cutting process, the laser cut some of the pieces too much, so that they did not fit correctly. As a solution to this, the pieces were sanded to find the perfect fit without looseness.

On the other hand, the base piece was formed by attaching four smaller square pieces to it. (*Figure 104*)

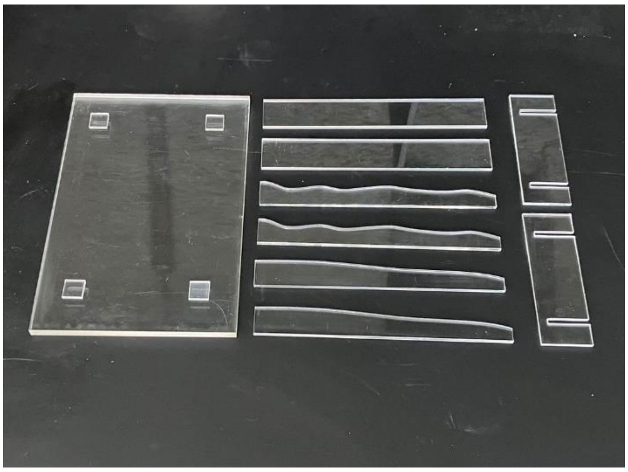

Figure 97: Laser cut acrylic pieces.

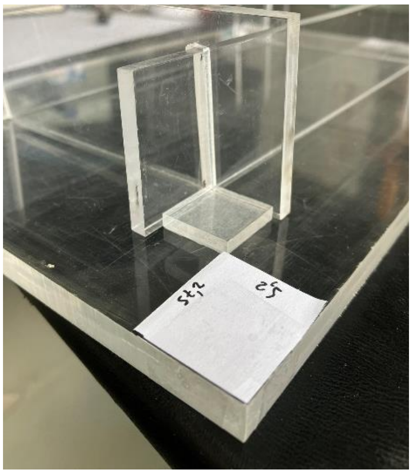

Figure 98: Placing the small squares process.

STEP 3: FITTING THE PIECES TOGETHER

To fit the pieces together, simply insert the straight pieces into the grooves of the slot pieces. This forms a rectangle with 4 pieces (*Figure 105*). These pieces are placed on the base and are delimited by the 4 small squares (*Figure 107*). The task is easier if the slot pieces are placed upside down to be joined with the other pieces (*Figure 106*).

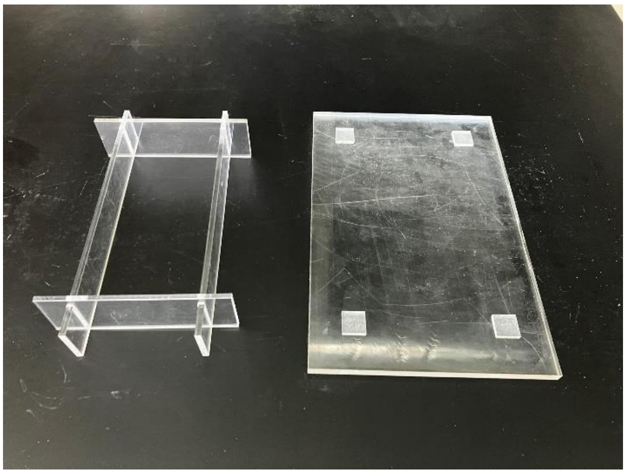

Figure 99: Pieces assembled next to the base piece.

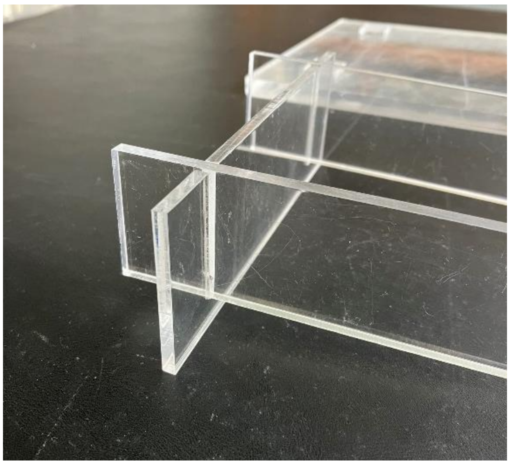

Figure 100: Slot piece placed upside down to ease the assembly.

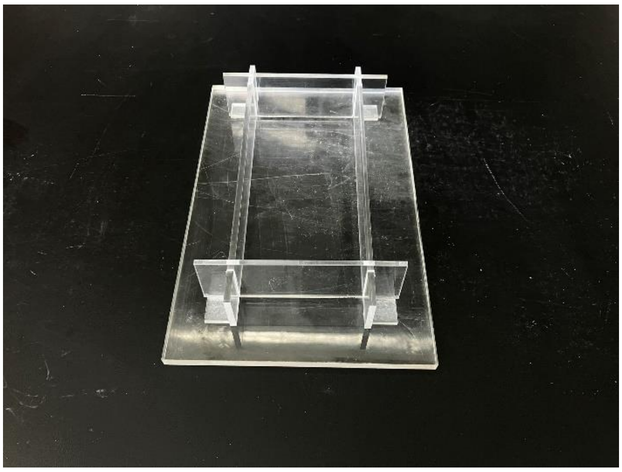

Figure 101: Pieces assembled placed onto the base piece.

STEP 4: MOULD FILLING

Once we have the shape of the mould, we proceed to introduce the clay into it little by little until it is full (*Figures 108 and 109*). The technique used is press moulding, which consists of pressing the clay with the hands or with a tool until a compact block is created.

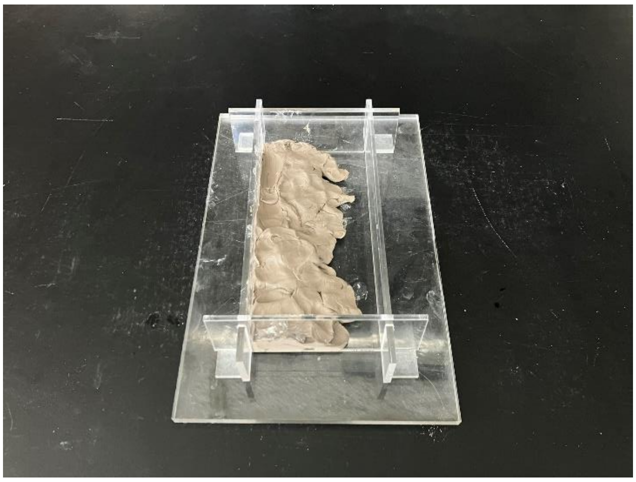

Figure 102: Mould being filled up with clay.

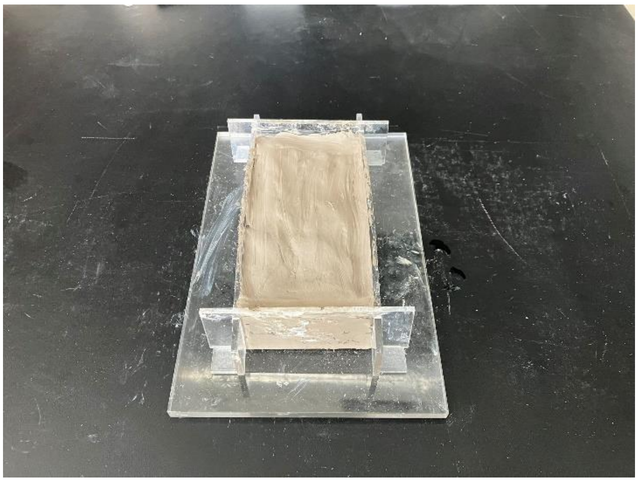

Figure 103: Mould full filled up.

STEP 5: PIECES REPLACEMENT

Once we have the clay block it is time to dismantle the pieces. We must separate the pieces from the block and from each other (*Figure 110*). Next, we position the pieces with the wavy shape on the sides, allowing them to stick to the clay (*Figure 111*). Finally, it is not necessary to put the slot pieces again, as the shape pieces get stuck to the clay and are in no need to be held.

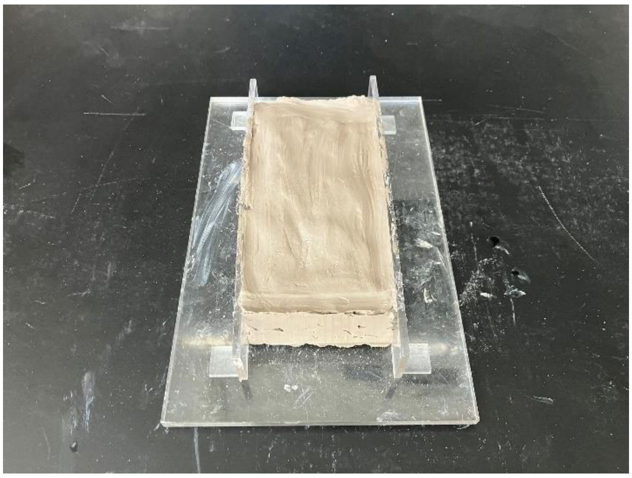

Figure 104: Kit with the slot pieces removed.

Figure 105: Shape pieces placed in the block.

STEP 6: WIRE CUTTING

Thanks to the humidity of the clay, the block sticks to the acrylic base. This makes it easier for us to cut with the wire following the shaped pieces as a guide.

STEP 7: SEPARATING THE PIECES

Finally, all that remains is to separate the pieces from the block and leave it to dry. This last step is important as, in order to remove it from the base, we need the clay to dry first. (*Figures 112 and 113*)

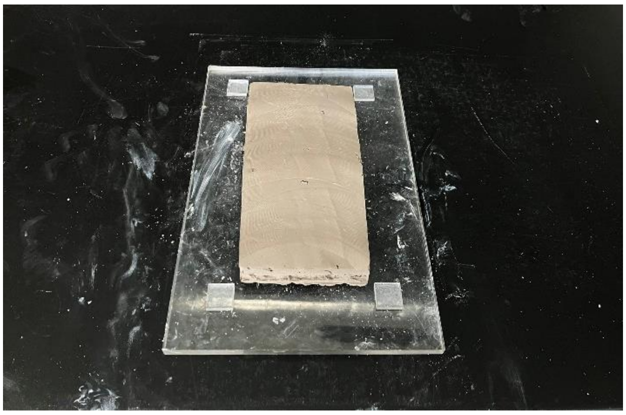

Figure 106: Clay block with pieces removed.

Figure 107: Clay block moulded and cut with shape.

4.2.2. TYPES OF PIECES

Below are pictures (*Figures 114-118*) of each type of piece that belongs to the kit. Each one is made of acrylic plastic and cut with laser cutter.

4.2.2.1. PIECE WITH SLOTS

This piece goes on the sides of the width of the block and has grooves to join with the straight pieces of the length.

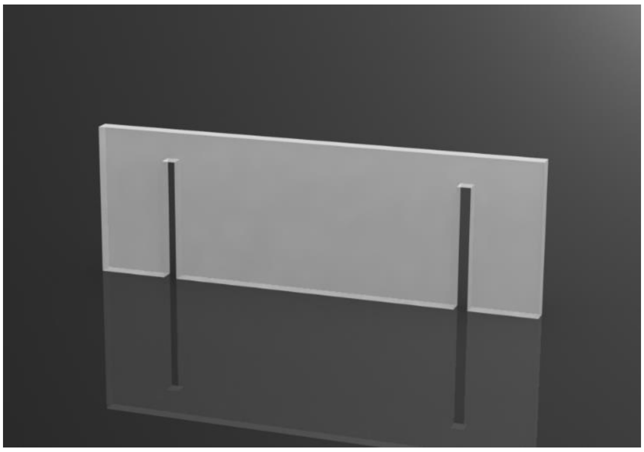

Figure 108: Slot piece.

4.2.2.2. STRAIGHT PIECE

This is placed in the lengths of the block, inside the grooves of the previous piece.

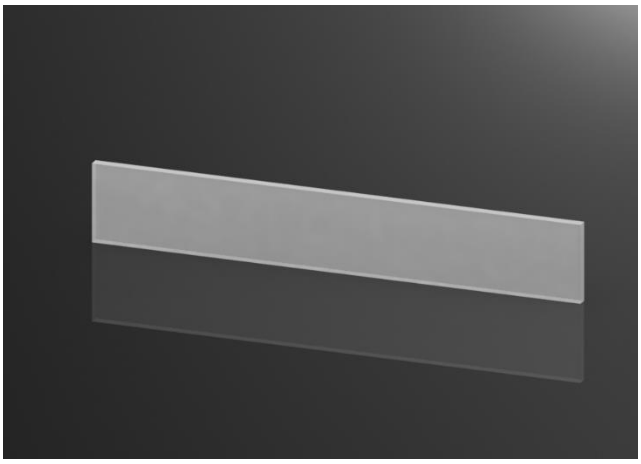

Figure 109: Straight piece.

4.2.2.3. PIECES WITH SHAPE

These pieces allow the user to cut the block to the desired shape. They are combinable and reversible so they can offer various cutting designs.

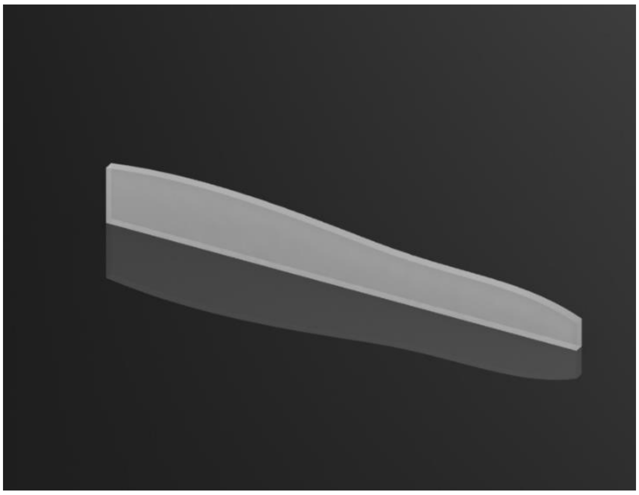

Figure 116: Piece with shape number 1.

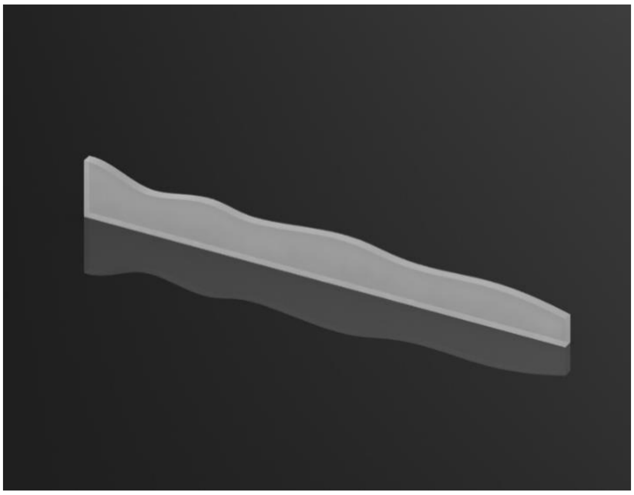

Figure117: Piece with shape number 2.

4.2.2.4. BASE PIECE

This is the largest piece and has four smaller square pieces glued to it.

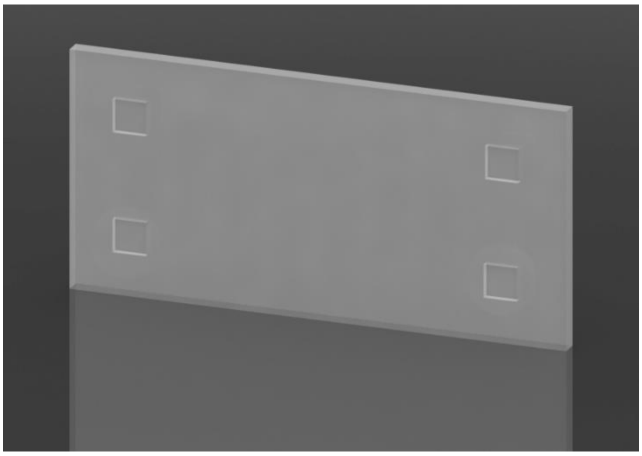

Figure 110: Base piece.

Further details of the design process of these pieces are presented in Annex 3. Also, in this annex you could find final designs applied to the whole kit.

4.2.3. TESTS

Tests have been carried out using this technique. (*Figures 119 and 120*)

Figure 111: Moulding and wire cut tests.

Figure 112: Clay blocks moulded and shaped.

4.2.4. DRAWINGS AND MEASUREMENTS

Drawings and measurements of each piece designed are presented on Annex 1.

5. FINAL RESULTS

5.1. USE OF EXTRUSION AND WIRE CUT PROCESS FOR DESIGNING MODULAR FAÇADE ELEMENTS

5.2. USE OF MOULDING AND WIRE CUT PROCESS FOR DESIGNING MODULAR FAÇADE ELEMENTS

5.1. USE OF EXTRUSION AND WIRE CUT PROCESS FOR DESIGNING MODULAR FAÇADE ELEMENTS

As mentioned at the beginning of the project, the exploration and study of techniques for modelling and cutting clay was carried out with the aim of being able to design modular elements that would later be used in the design of a façade. Ceramic is a material that has recently been used in architecture and which offers new possibilities in this context.

Inspired by decoration and 'kobogó' style, we have designed a clay piece (*Figure 121*), manufactured thanks to one of the designed dies, which can be reproduced multiple times with the wall extruder.

Figure 113: Clay final prototype.

This piece, created from the U-shaped die, can be multiplied to create a harmonious and original pattern, creating a panel. This panel can be used both as decoration on a wall or façade and as a separating element between rooms.

The creation of this piece begins with the extrusion of a U-shaped profile, which is then cut with wire to form a triangular piece. The process starts with the extrusion of the clay, continues by making the cutting marks and cutting (*Figures 122-124*), and ends by perfecting the surface of the piece until it is uniform. This last step is possible thanks to the use of water on the surface of the piece. The conception process of this idea can be seen in detail in the Annex 2.

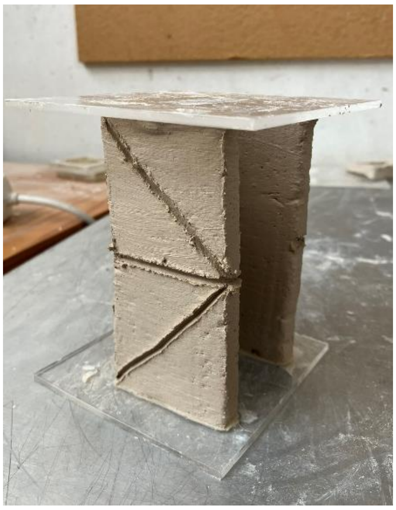

Figure 122: Extrusion with cutting marks.

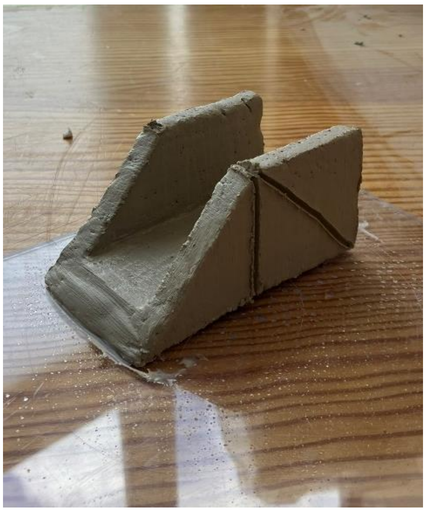

Figure 123: Workpiece of extrusion cut.

Figure 124: Creation of two pieces.

The way these pieces are placed is crucial to have a panel (*Figure 125*) with gaps through which light can pass. Also, the way in which these pieces are multiplied is important because, depending on where we look at the panel from, we will see different shapes. If we look at the panel from the side, we will see triangles, and if we look at it from the front or from the back, we will see rectangular holes through which we can look through the panel.

Below you can see what the piece would look like in panel form and seen from different perspectives. (*Figure 126-129*)

Figure 114: Panel prototype render.

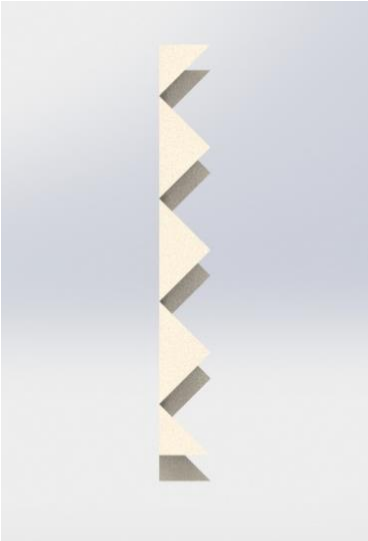

Figure 126: Side view of the panel.

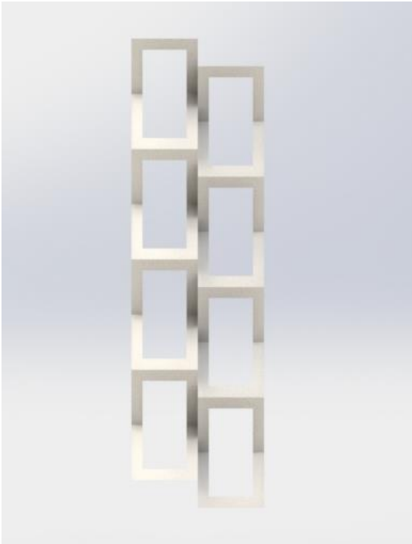

Figure 115: Front view of the panel.

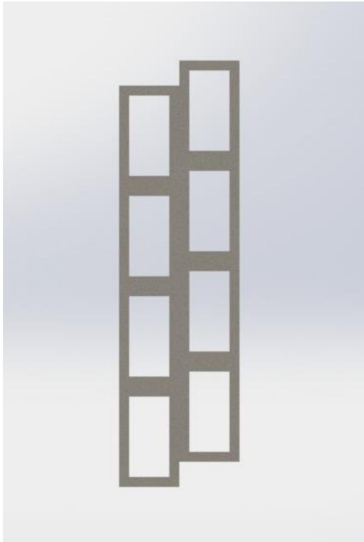

Figure 128: Back view of the panel.

Figure 116: Panel prototype render 16-piece module.

Some prototypes of the piece have also been made in order to be able to observe a 12-piece module and see how it would look in reality. (*Figures 130-132*)

Figure 117: Clay final prototypes position 1.

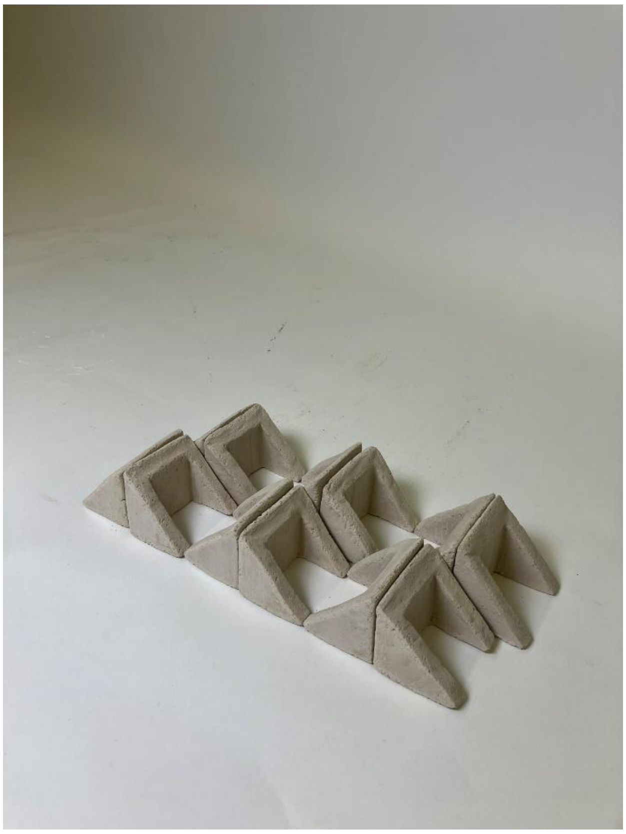

Figure 118: Clay final prototypes position 2.

Figure 119: Clay final prototypes position 2 with zoom.

5.2. USE OF MOULDING AND WIRE CUT PROCESS FOR DESIGNING MODULAR FAÇADE ELEMENTS

The second part of the project focuses on the technique of moulding combined with wire cutting, with the same goal as the first part; to design a modular element.

The main idea is that this modular element can be created and reproduced more than once. Therefore, a reusable clay moulding and cutting kit has been created. (*Figures 133 and 134*)

This kit should be easy to use and clean, and it should also allow you to create a block of clay and a precise cut of the clay. For this reason, the material used is acrylic plastic, light in weight and easy to clean. It has two ways of use. The first one is with some straight pieces that will allow you to form the block by moulding the clay. The second way would be with the template pieces with different designs that will allow you to guide the cut with a specific shape.

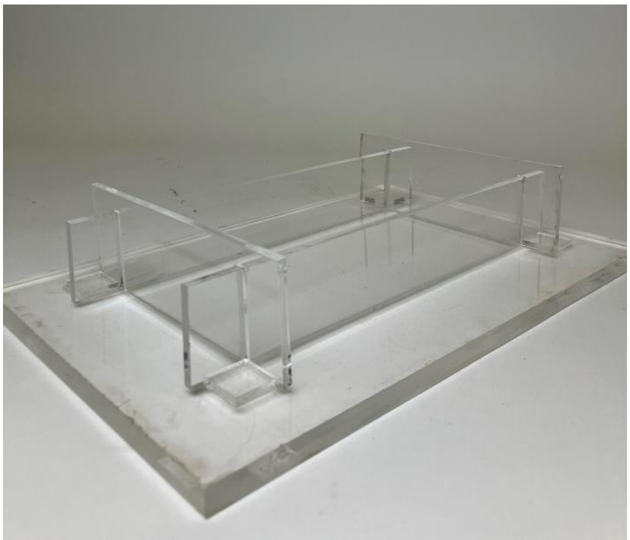

Figure 120: Kit pieces positioned for moulding.

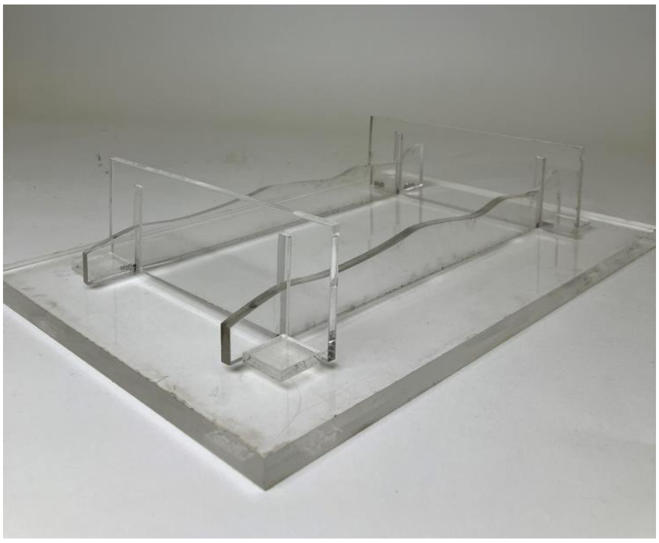

Figure 121: Kit pieces positioned for cutting.

The design of this kit allows you to facilitate the task of moulding and cutting, in this way, as well as its maintenance and the creation of a repetitive piece (*Figure 135*). The process of using this moulding and cutting kit has been detailed previously in section 4.2.1.

Below is an image showing how the creation of a modular element made with the kit could also be applied to the design of a panel. (*Figure 136*)

Figure 122: Modular clay block.

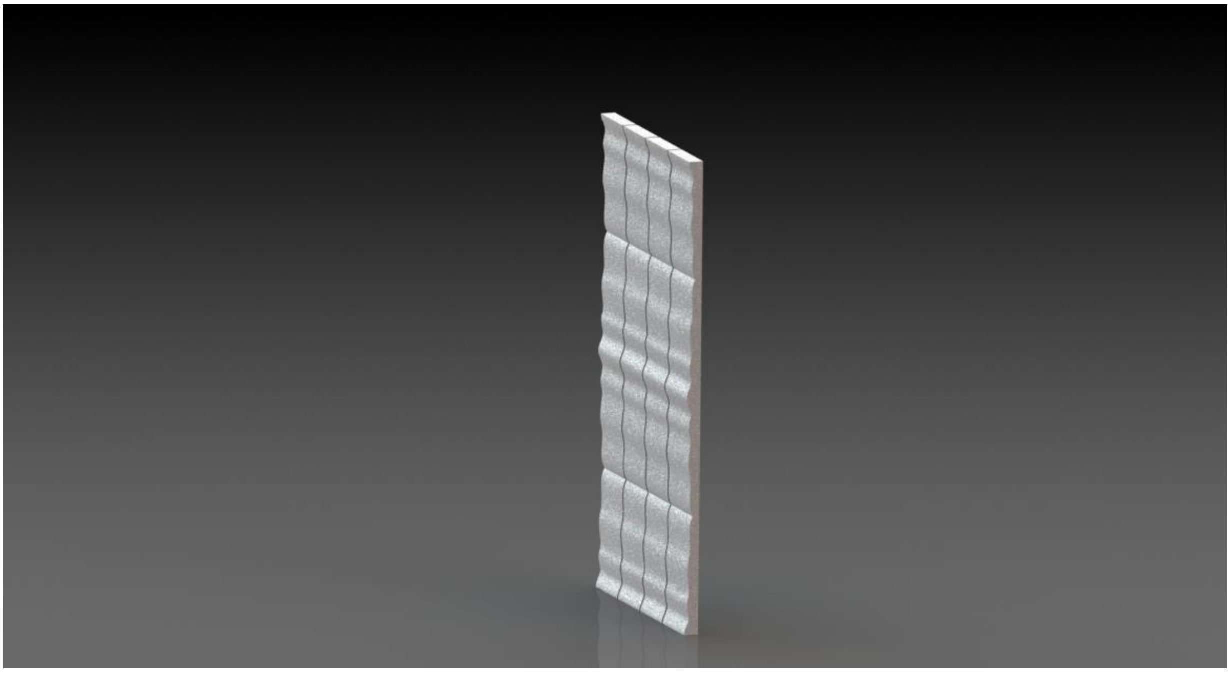

Figure 123: Clay block created with kit in panel render.

Some other relevant images about this whole research will be found in Annex 4.

CONCLUSIONS

To conclude this project, I believe that the use of materials such as ceramics and clay is constantly growing for construction and architectural elements. The use of various manufacturing techniques is a valid way to work with these materials and experiment with the infinite possibilities of geometries and shapes. Also, it has been concluded that clay is a very versatile material to manipulate and work with, and to use in numerous projects.

In this research project, it has been demonstrated how the use of different clay manufacturing techniques such as extrusion, moulding and wire-cutting can be used in the architecture design context.

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ANNEXES

ANNEX 1. DRAWINGS AND MEASUREMENTS.

ANNEX 2. SKETCHES AND DESIGN PROCESS. EXTRUSION.

ANNEX 3. SKETCHES AND DESIGN PROCESS. MOULDING.

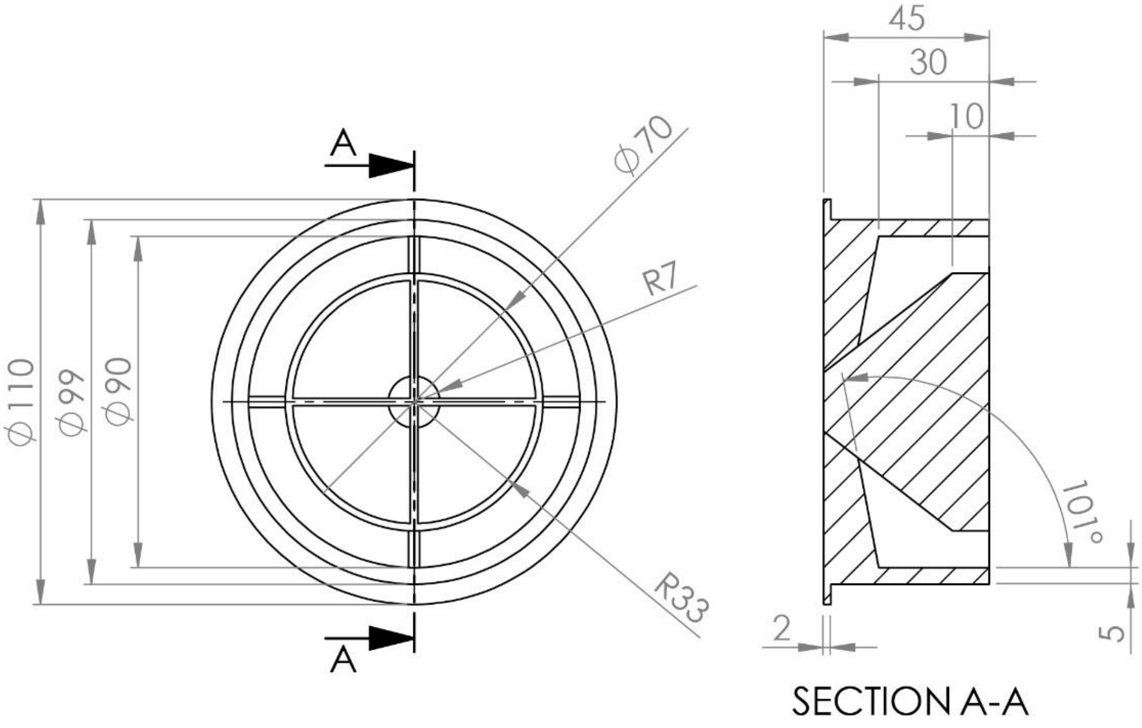
ANNEX 4. GALLERY OF IMAGES.

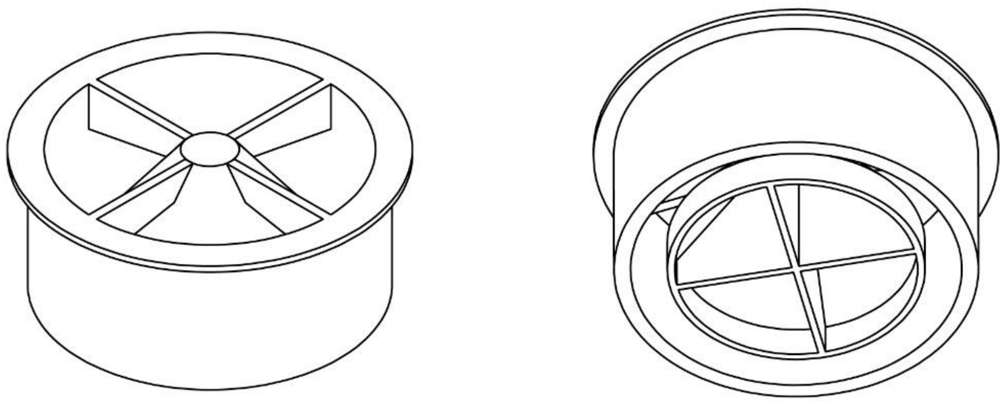
ANNEX 1. DRAWINGS AND MEASUREMENTS.

In this annex you will find the drawings of each of the pieces where you can see their geometry and measurements.

1. **EXTRUSION**
    1. CYLINDER_DIE
    2. SQUARE_DIE
    3. TRIANGULAR_DIE
    4. E_DIE
    5. U_DIE
    6. H_DIE

2. **MOULDING**
    1. KIT
    2. BASE_PIECE
    3. SLOT_PIECE
    4. STRAIGHT_PIECE
    5. SHAPE_1
    6. SHAPE_2





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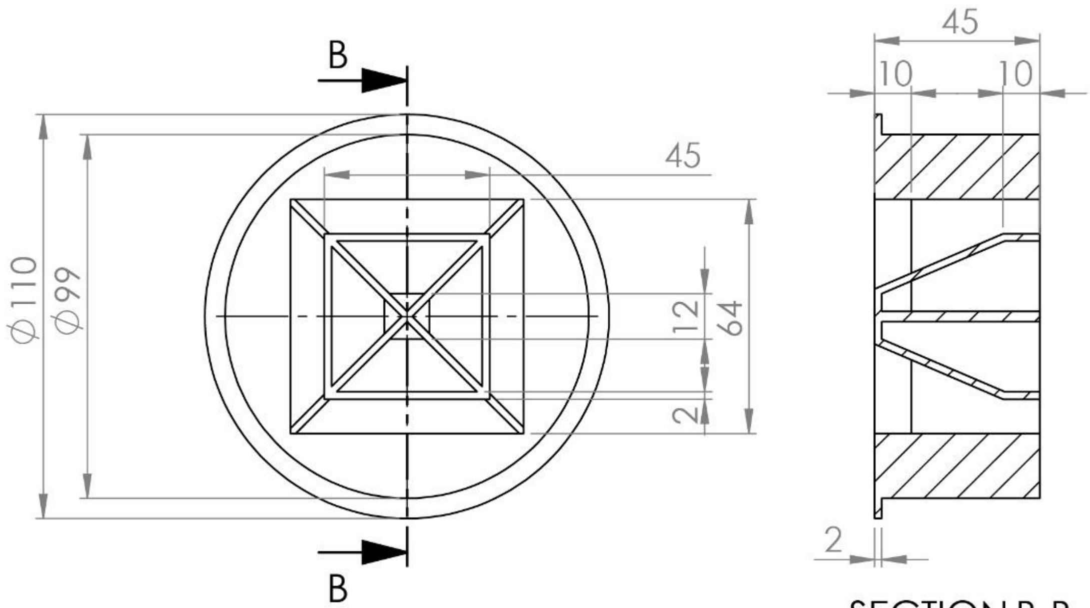

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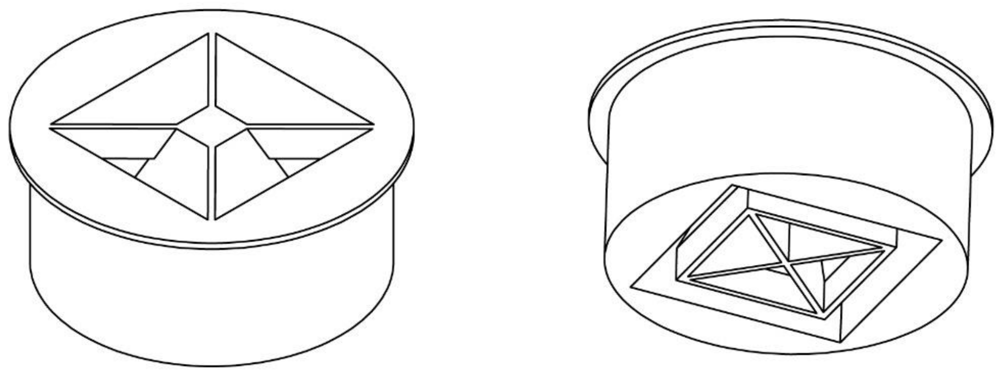

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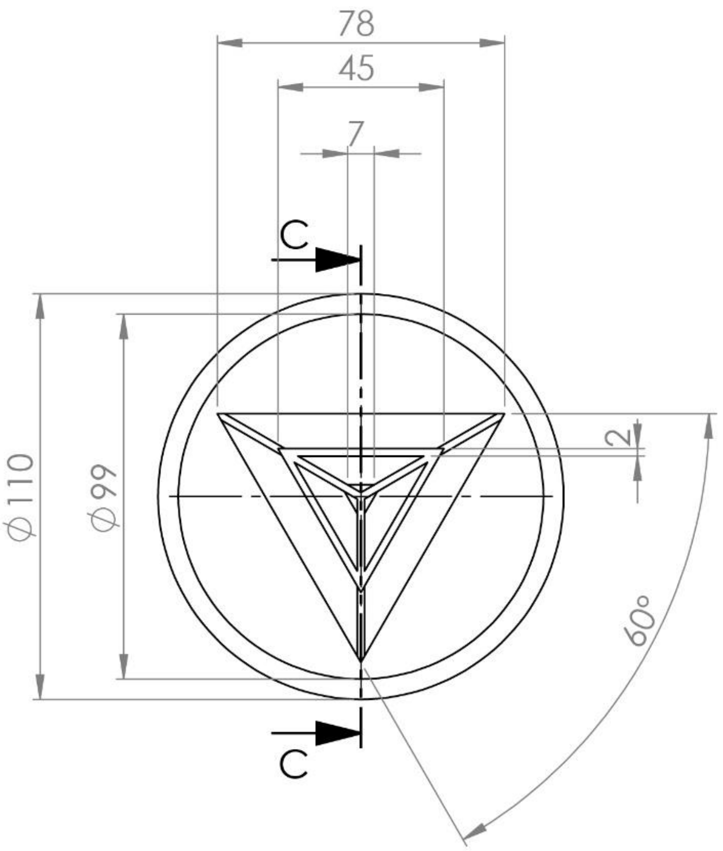

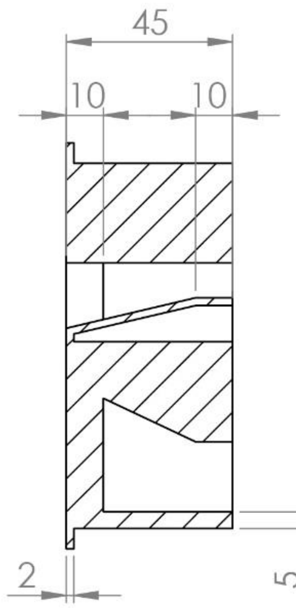

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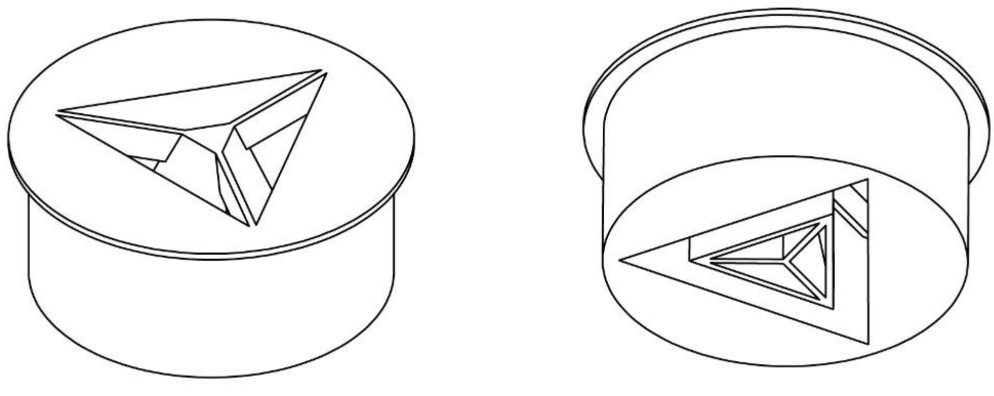

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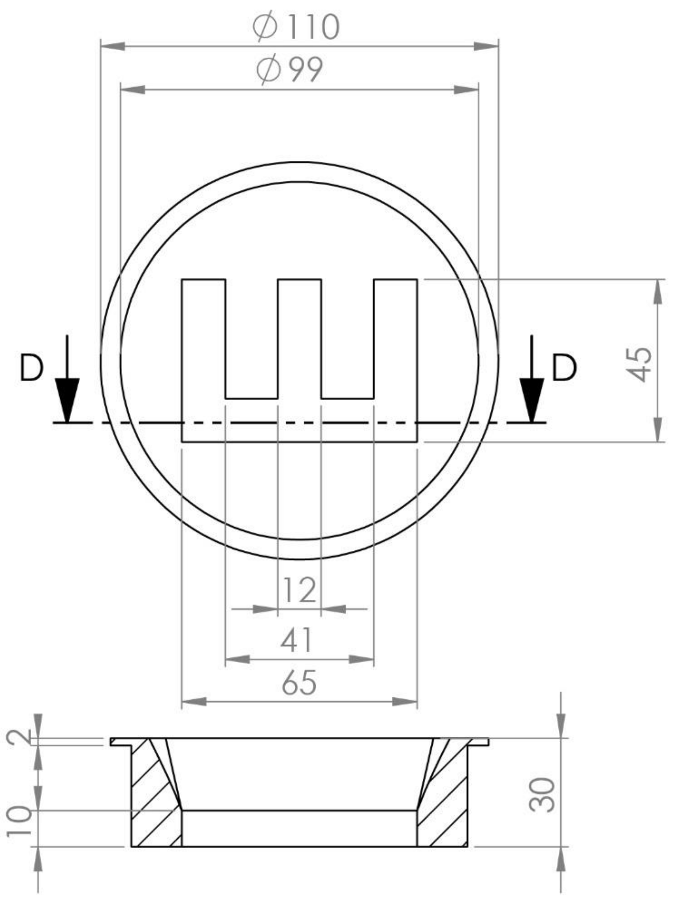

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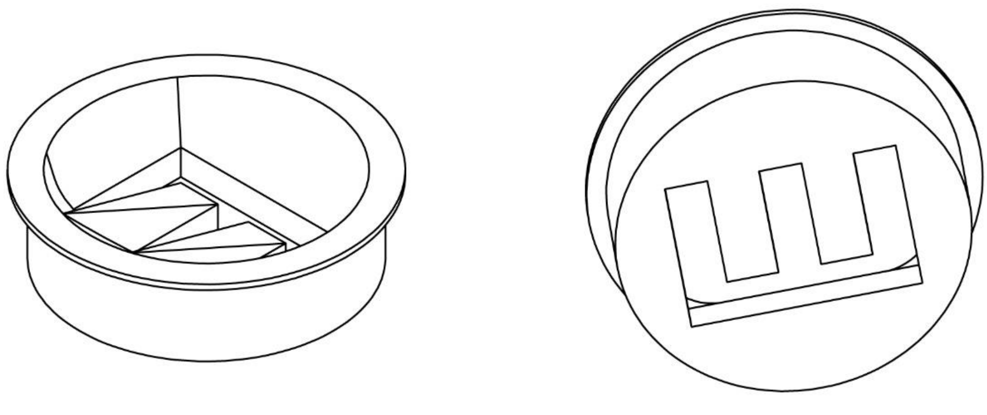

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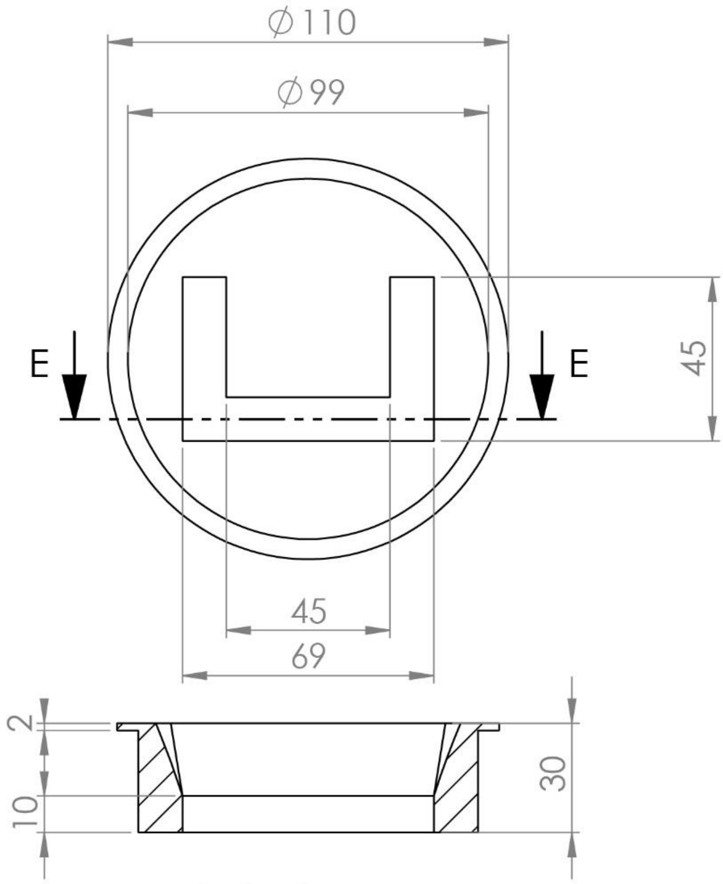

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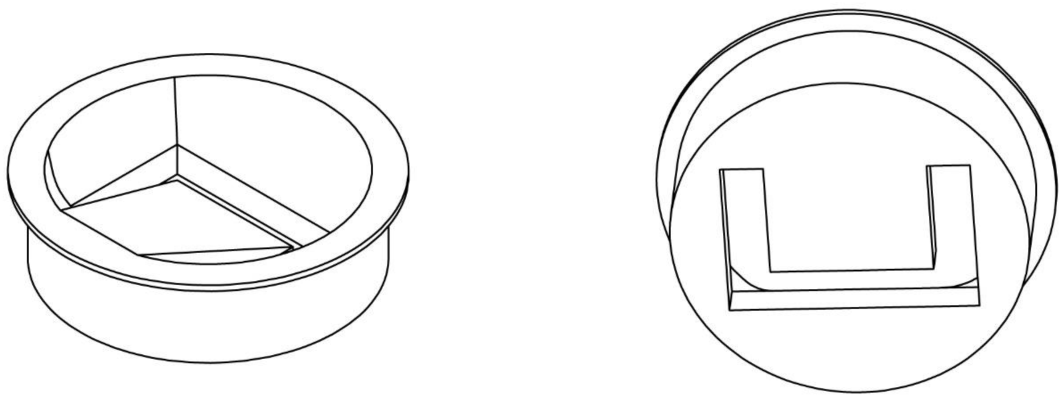

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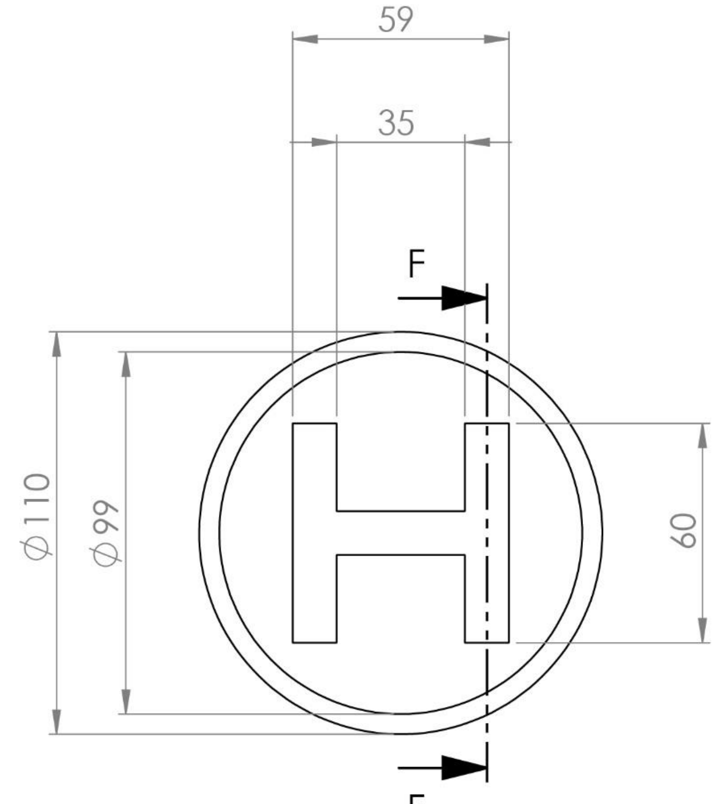

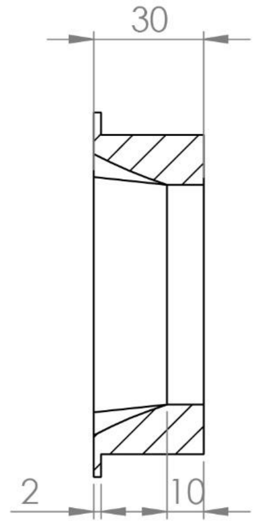

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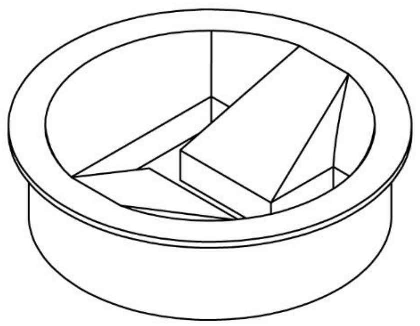

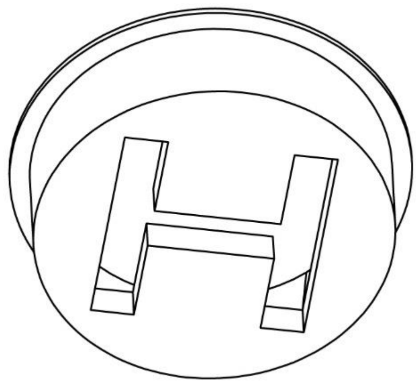

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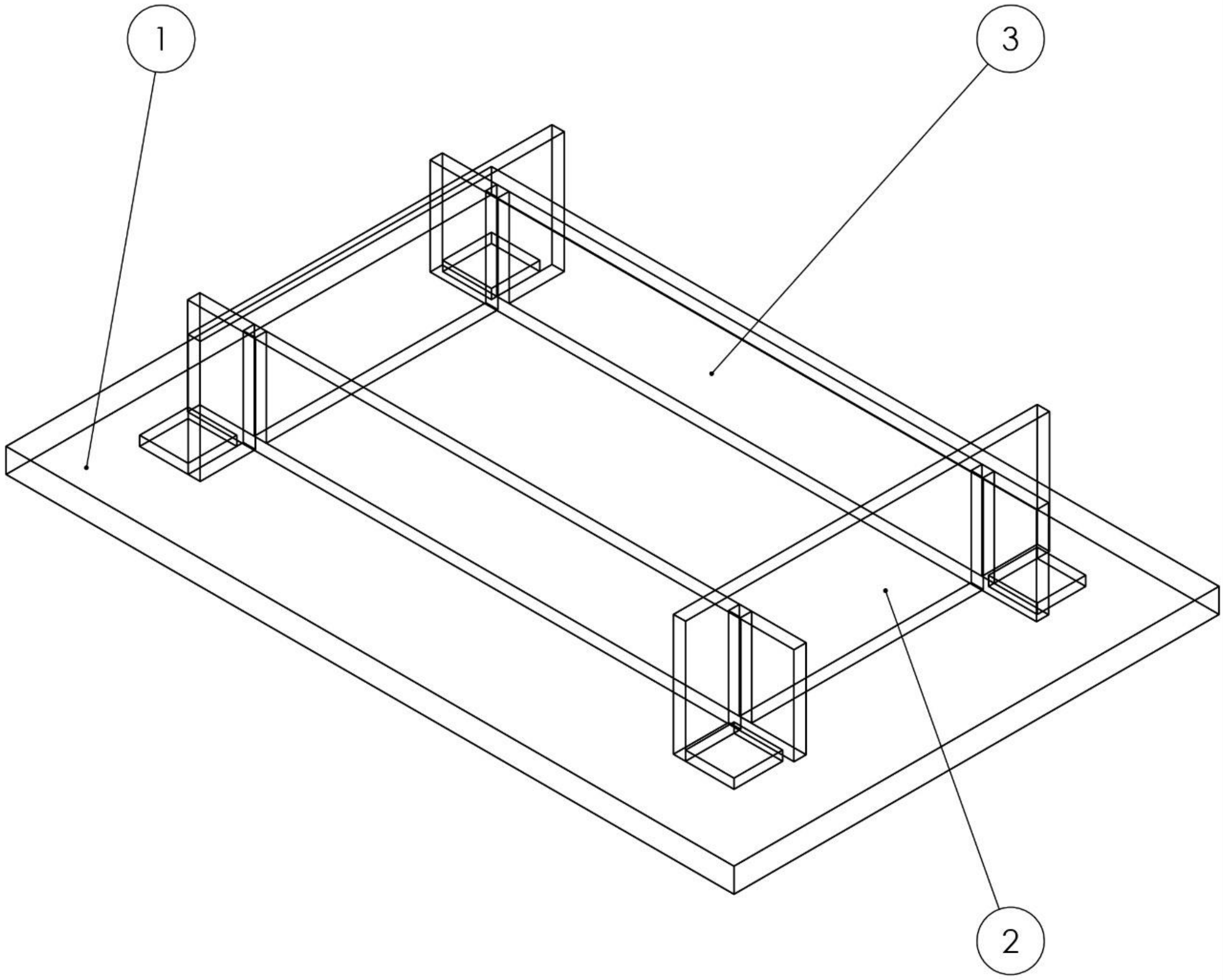

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3	2	STRAIGHT PIECE	STRAIGHT_PIECE
NUMBER	QUANTITY	DESIGNATION	PIECE CODE

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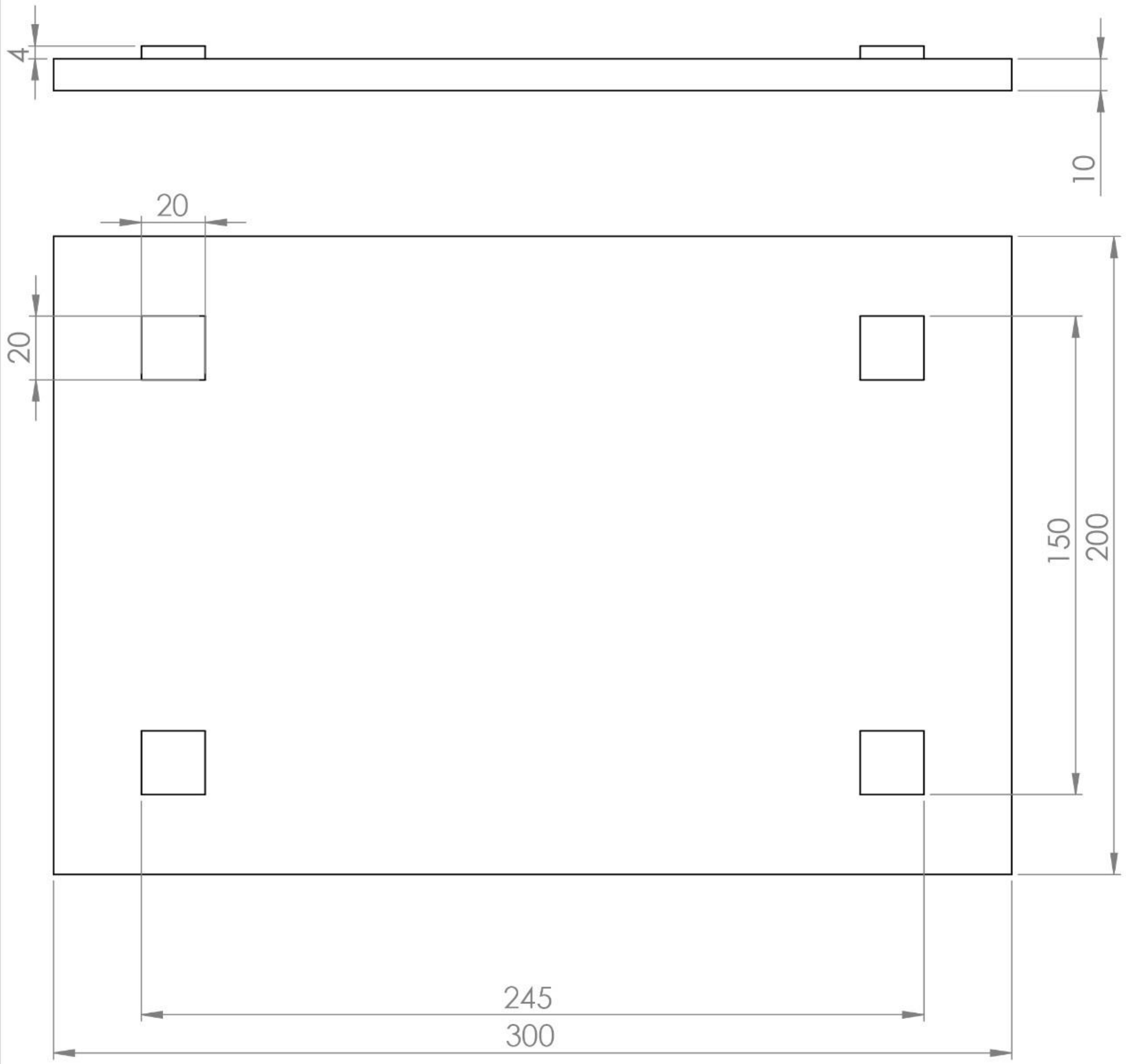

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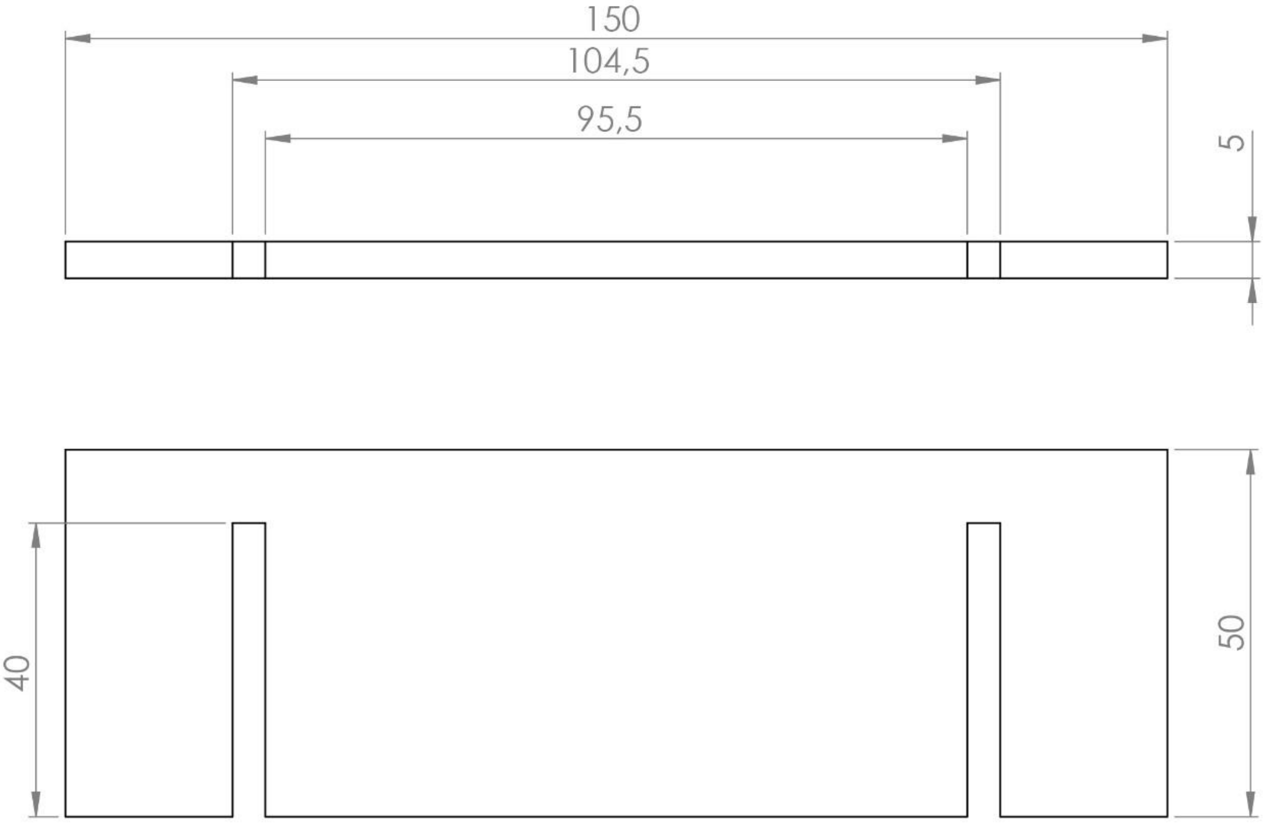

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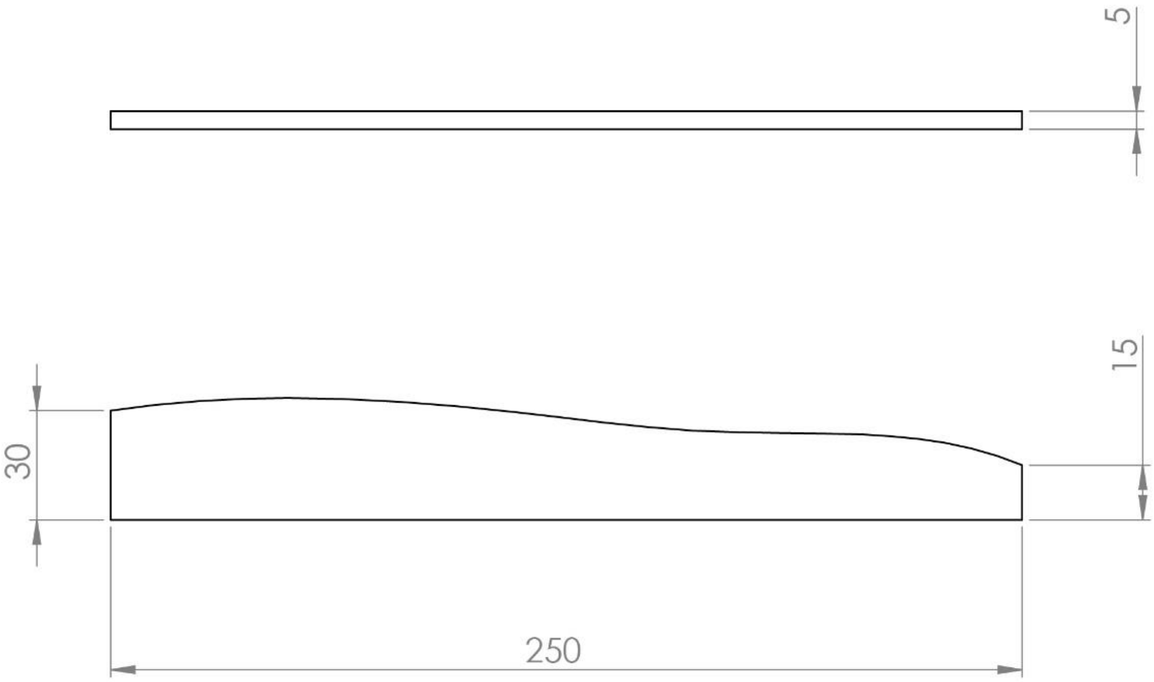

29/05/2024

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Client: PROJETO INDÚSTRIA

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SHAPE 1

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Universidade do Minho
Escola de Arquitetura, Arte e Design

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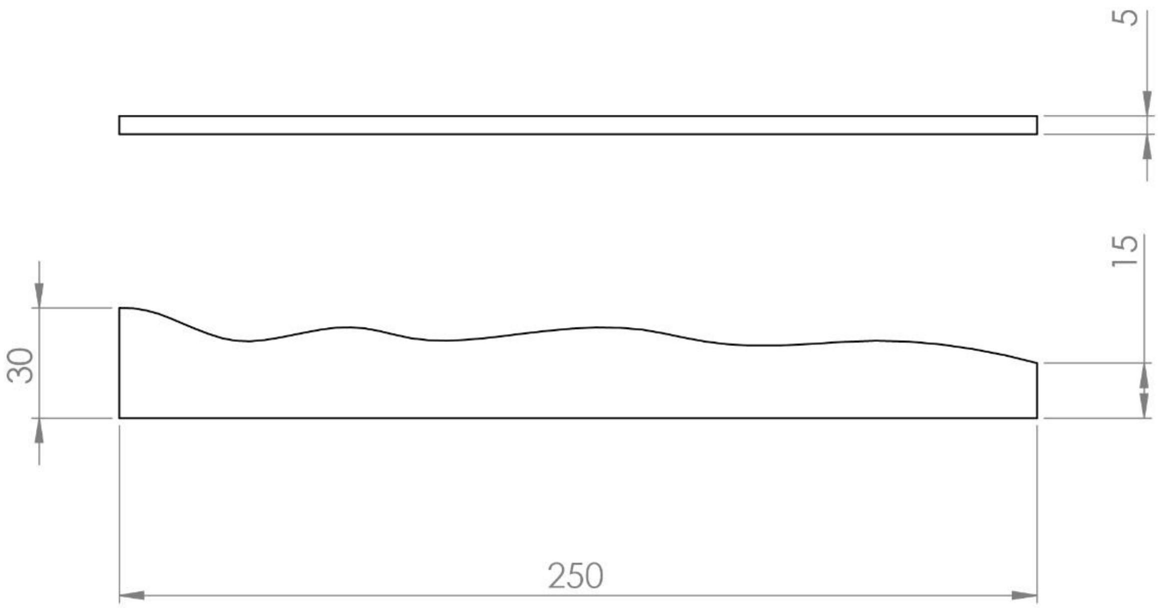
Version: 1

Sheet nº 5 / 6



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Escola de Arquitetura, Arte e Design

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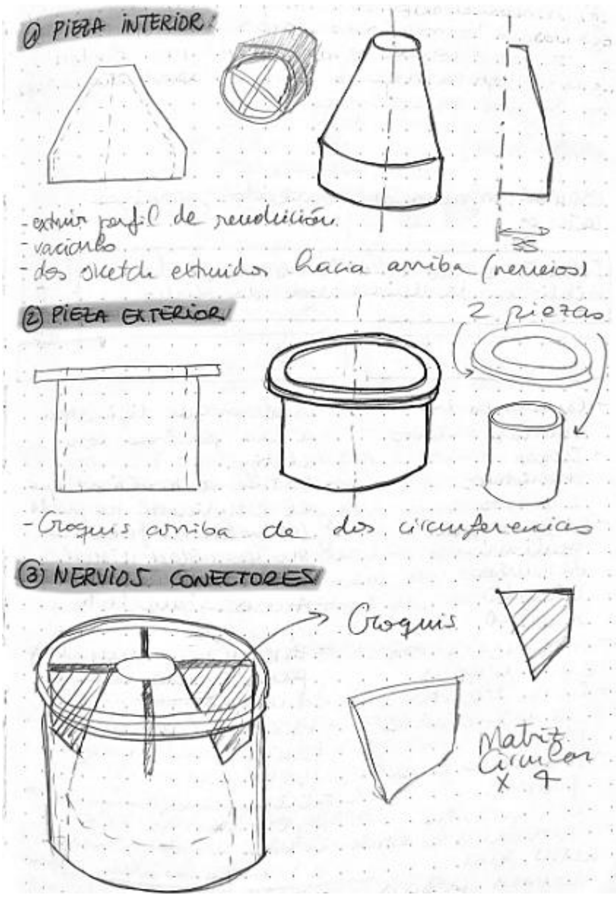
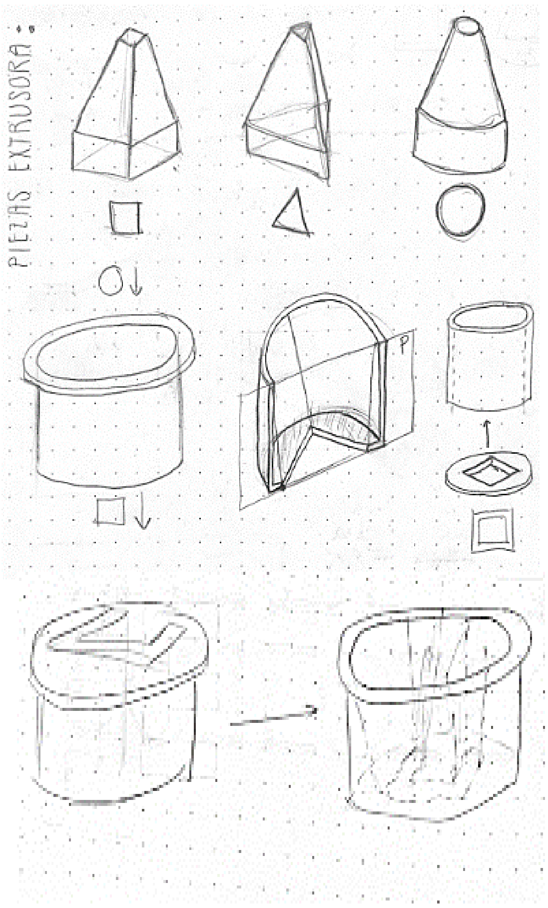
ANNEX 2. SKETCHES AND DESIGN PROCESS. EXTRUSION.

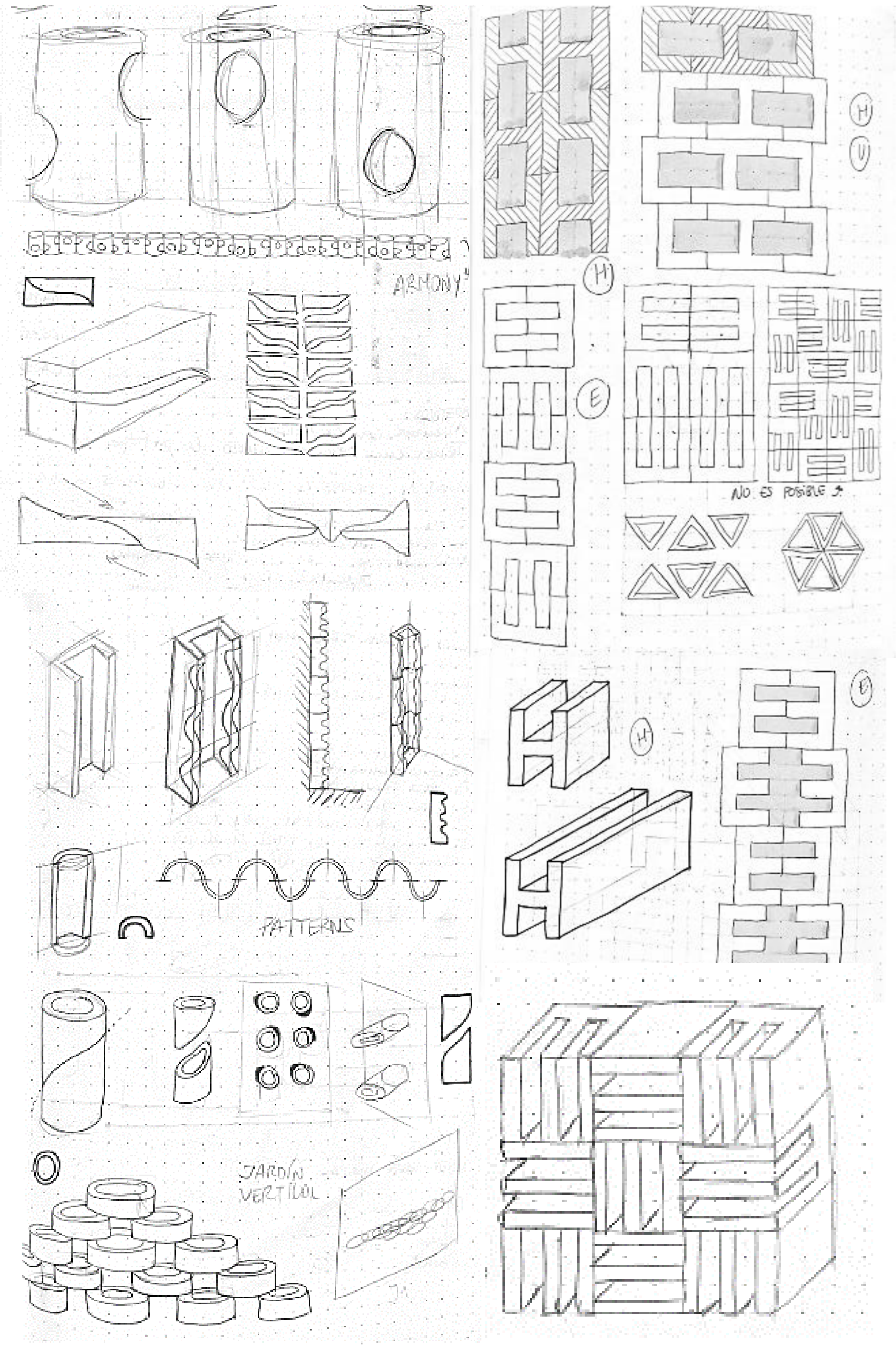
In this annex there are presented sketches and previous ideas of the process and designing of extrusion.

SKETCHES FOR THE DIES DESIGN PROCESS



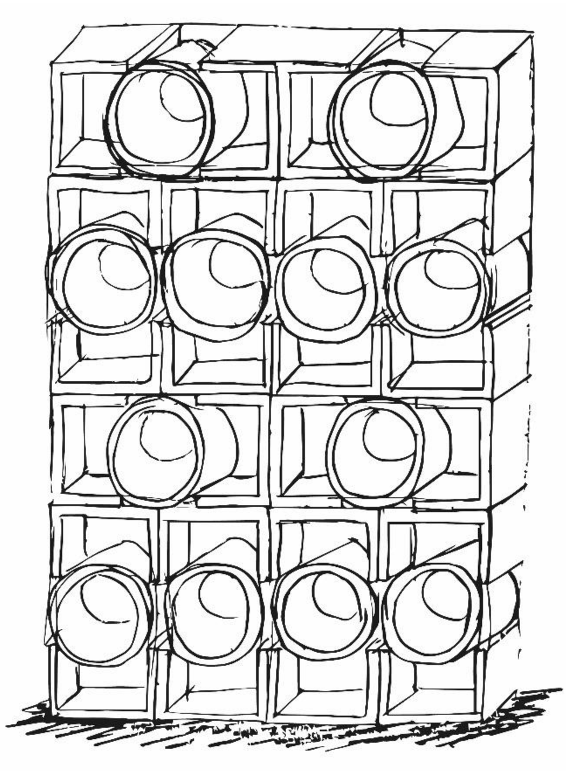


SKETCHES FOR EXTRUSION TESTS

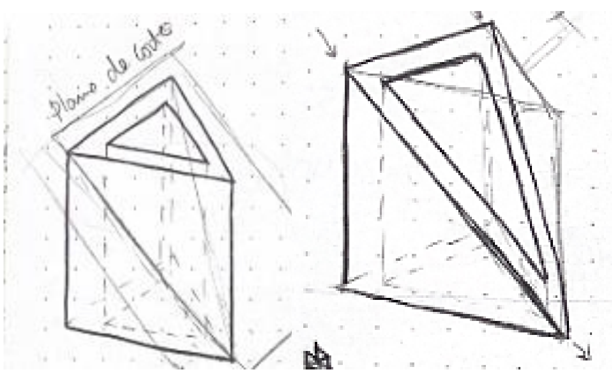


FINAL PROPOSAL DESIGN PROCESS

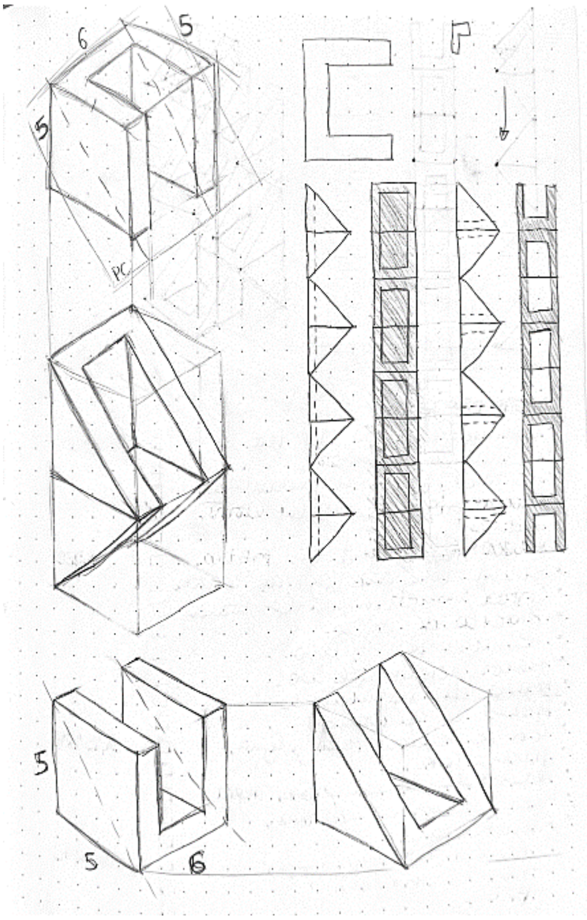
Firstly, ideas were experimented with combining designs from different dies. Extrusions of pieces from the shape collection were combined with pieces from the letters collection and a mock-up was made in cardboard and tested in clay.

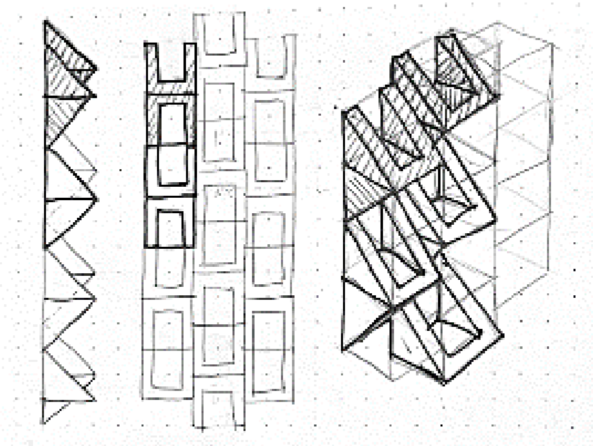


Then, some other tests were made in order to get to the final proposal.



In the end, the final design was arrived at through this process of combining cutting on an extruded piece.

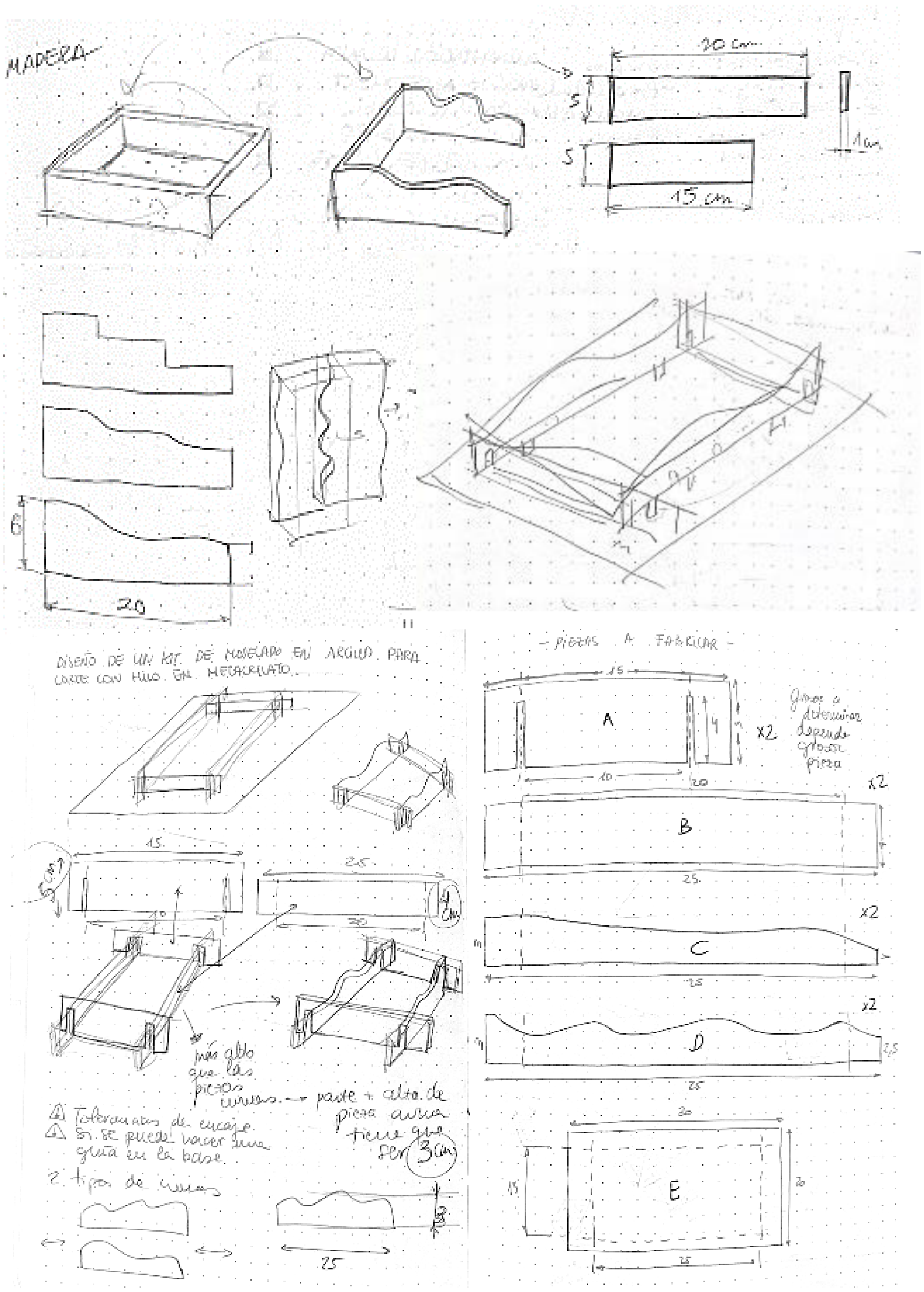




ANNEX 3. SKETCHES AND DESIGN PROCESS. MOULDING.

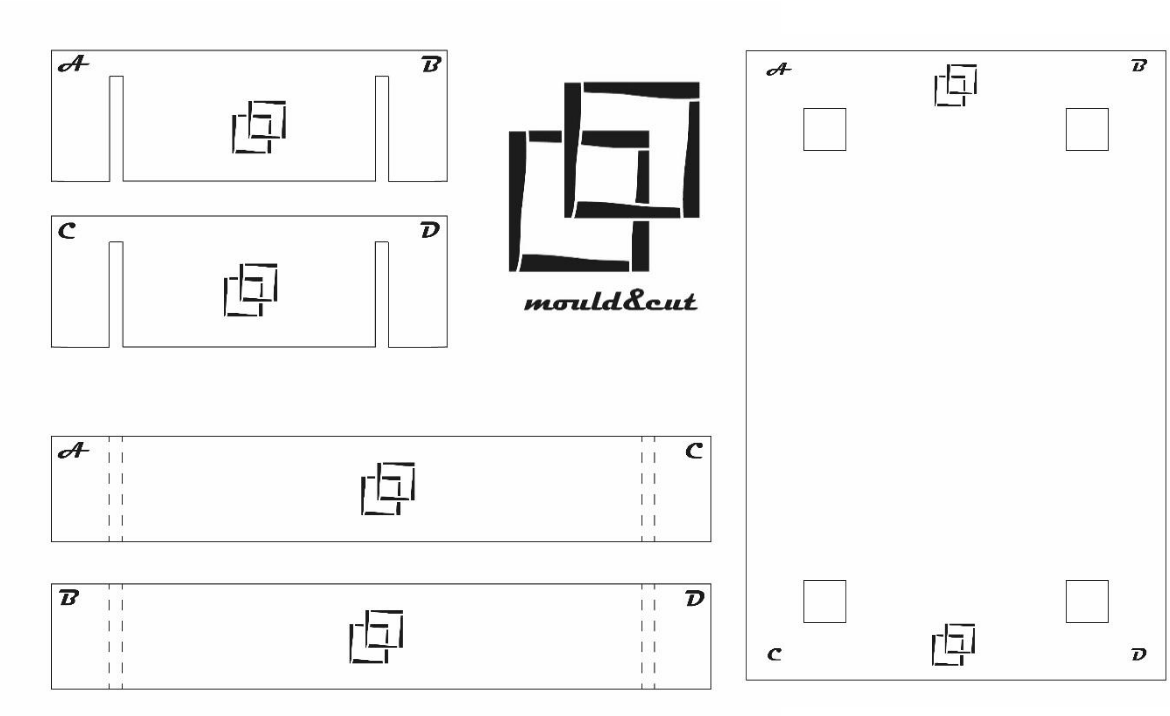
In this annex there are presented sketches and previous ideas of the process and designing of extrusion.

SKETCHES FOR THE MOULD AND SHAPE TEMPLATES DESIGN PROCESS



NAME AND LOGO DESIGN FOR THE KIT AND ENGRAVING OF THE PIECES

To complete the creation of the moulding and cutting kit, a series of engravings have been designed to facilitate the use of the kit in this way as well as to improve its appearance and aesthetics. This action will be carried out with laser on the pieces as shown in the image. A logo and a box have also been designed in case a brand would like to market this kit.



ANNEX 4. GALLERY OF IMAGES