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DIRECT FIBRE GLASS/POLYESTER RESIN MODELLING AND CASTING AS A TECHNIQUE IN SCULPTURE PRODUCTION

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Abstract

As civilisation thrives, the art of Sculpture continues to lend itself to new techniques and latest industrial materials as mediums for production. From the most basic tools such as stones and iron chisels, to pneumatic machines and 3D printing technology. The materials for sculpture making have also pluralized as much as the interpretations of what is and what is not art, has continued to populate the contemporary art discourse. The current study therefore dives into the experimental approach to materials and their uses, particularly, using an industrially common material, ever since the turn of the 21st century; polyester resin and fibre, to approach sculpture making in an entirely different technique as commonly applied in the field of sculpture. This is done in order to solve the problem of demand on the time required to execute a piece of sculpture. The direct modelling with polyester resin and fibre glass with the aim of achieving a realistic horse sculpture was attempted by the researcher. The results achieved were much more naturalistic then they were realistic. It was however established that the technique is a faster approach to sculpture making than the traditional modelling and casting methods, this is achieved by by-passing the two stages of clay modelling and mould casting. Nevertheless, the technique is most suitable for sculptural projects with less intricate parts and more of plainer surface areas.

Keywords: Casting, Fibre Glass, Modelling, Polyester Resin, Sculpture Production

Introduction

Fibreglass as a medium for sculpture is relatively new when compared to other older materials for sculpture such as stone, wood, and bronze. However, over the last few years, it has grown in popularity among sculptors as a choice medium for production mostly due to its lightweight and portability, aa well as its availability in industrial quantities.

Mata Pan (1961) is one of the early sculptors who worked with Fibreglass. In Nigeria, the medium became popular for sculpture making around the late 80s. Although due to its thermostatic nature, it could be set within a short time, utilizing this speed of setting in making sculpture pieces is the number one challenge a sculptor faces when he chooses to work using the direct fibreglass casting technique. This current research is therefore concerned with employing the above stated technique to utilize this single attribute of the medium to produce two life-size horse sculptures; thereby significantly reducing the time required to execute the sculptures, while achieving desirable results. This study is most significant because by meticulously noting down every stage of the technique, the researcher makes it easier for any sculptor who wishes to employ the technique to follow through.

Research problem

The challenge of effectively and efficiently delivering a sculptural piece within a short period of time is indeed a real issue among sculptors. Most times, in order to beat this meagre time, sculptors experiment and vary their choice of materials and techniques in order to arrive at a desirable piece that would satisfy the client. One of these techniques involves the use of the direct fibre-glass casting method which as this study would show, reduces greatly the amount of time spent on a given piece as well as reducing the amount of work to be done in realising a sculptural work.

Significance of the study

This study is significant as a working documentation of the processes of direct casting with fibre glass and epoxy resin. It is therefore a resource book for sculptors working on the technique for the first time and a reference point for future studies for scholars and sculptors. The study also adds up to the available literature on fibre glass and resin as a sculpture medium.

Also, this study would be the first documented trial of the technique in the sculpture studio of fine and applied arts department in Nnamdi Azikiwe University, Awka, it is therefore hoped that it would inspire more researches into the medium and method within the studio.

Aim and objectives of the study

The aim of this research is to investigate the formal possibilities in modelling with fibre glass and epoxy resin to establish if the technique is faster as compared to other traditional methods of modelling and casting.

The specific objectives include:

1. To produce two above life-size sculptural works (horses) using the technique of direct fibre glass and epoxy resin casting.
2. To record the observations and material behaviours of the mediums used in the works,
3. To draw comparisons between works done using traditional modelling and casting techniques and the technique in view; with the aim of ascertaining which method is faster and more economical
4. To study related literature on the subject, discover literature gaps and fill in such gaps, thereby contributing to scholarship on materials and methods in sculpture.

Scope of the study

For sake of clarity and specificity the researcher has decided to concentrate on the production of two horses (a horse and her young foal) using the techniques of direct fibreglass and epoxy resin modelling.

Literature Review

There are numerous books and literature on materials and techniques of sculptural productions. A lot of them deal on the versatile materials that abound in our world, which are put to use in making sculptures. However, books dealing on the use of Epoxy resin and fibre glass for making sculptures are relatively few. Fibreglass is a new medium which was discovered around early 20^{th} century as an industrial material, subsequently gaining popularity among sculptors.

Conceptual framework

According to Mahmood, and Ahmed (2017), fibreglass is basically made of two substances epoxy resin and glass roving. This epoxy resin is a type of plastic polymer resin which is a product of petrochemicals. The resin is gelatinous in nature, and is mostly slightly colourless.

However, the first modern glass fibre as we know it today, that was ever made, was stumbled upon by a man named Dale Kleist while working to contrive the best way to weld two glass blocks together to form a complete seal. Kleist, a young researcher while working around the year 1932 with Owens Illinois Glass-company made this

accidental discovery while working with Game Shayter and Jack Thomas. The incident took place when a steam of compressed air is made to hit a stream of molten glass which creates a spring or splinters of glass fibres which he later partnership with Jack Thomas. The technique is known as "The Steam-blown process". The discovery of modern glass fibres notwithstanding, there was little use of this particular invention until Carlton Ellis produced the polyester resin which when combined with fibre glass produces a composite material suitable for many industrial products. In 1933 Ellis patented his invention, berthing a whole new world of possibilities in the industrial era of 20th century.

It however, took 8 years from then for the first commercial development of polyester for moulding to begin in the USA in 1941. This was the introduction of the heat curing alkyl casting resin. This type of resin requires the application of heat to initiate and quicken the curing process.

Moving forward, by 1946, polyester resins which contained styrene were used with peroxide acting as catalyst. This combination created the possibility of the mixture curing at cool temperature. Nicknamed the "cold cure" system, this is the precursor to the present polyester resin that we use today.

Polymer: according to McGrew-Hill Dictionary of chemical terms, polymer substance is one that is made of giant molecules formed by the union of simple molecules (monomers).

Chemical components of unsaturated polyester resin

According to Stamatakis, Knuutinen, Laitinen, and Spyros (2010), unsaturated polyester resins, UPR are products of reactions of polyhydric alcohols and dibasic acids or anhydrides which are then further dissolved and cross linked in unsaturated monomer of which the common one is styrene.

Modelling

Modelling in sculpture refers to the actual bringing into reality those forms and shapes the sculptor so desires. Unlike other methods of sculpture production, modelling is an addictive process which is realised by the building up of forms and volumes from the initial skeletal frame or armature usually made of metal or piece of wood. Rogers (1967) described modelling as essentially a process by which the forms of sculpture are built up piece by piece out of plastic materials like clay, wax and plastic.

Turner (1996) "The Dictionary of Art" came very close to describe the direct modelling method of working with fibre glass. The book identified two main methods employed by artists in working with fibre-glass, casting and the second which the book described as "the building up layers of resin-impregnated glass fibre material on to an armature or framework" pp (55). This captures the exact research approach to the present study, the book however added a caveat which reads, "This method has various commercial and industrial uses but is limited as a sculptural technique to abstract compositions" pp (55). Therefore, the research findings of the present study, hopefully, would reveal the reasons for this assertion, especially considering that the work in focus involves the sculpting of two horses (Naturalistically) using the latter technique.

Casting

When the modelling stage of a sculpture piece is completed, the sculptor is left with two options; leaving the work as it is in the original modelled state and material or casting it in order to transform it to a more permanent medium. This permanent medium may either be concrete, metal, or fibre glass composite or whatever other various medium with the ability to solidify and take up the shape of the mould into which it is poured. In order for a casting process to be initiated, there has to be in intermediate platform which serves as the negative cast, from which the resultants positive cast would be derived

from. This is known as "mould" it usually carries the impression of the original form of the sculpture in reverse state.

Casting according to Jate.org.uk (2021), involves making a mould and then pouring liquid material, such as molten metal, plastic, rubbers or fibre glass into the mould.

Now, the descriptions offered above are traditional definitions of the process of modelling and casting as involved in sculpture production; however, the concern of this study is to explore another possible method to arrive at a finished piece of sculpture by bypassing the intermediary first casting state which involves mould making, thereby moving straight to the positive casting piece is speedily realised without much delay, saving time and resources in the process. This is the purpose of this study as would be explored in an experimental manner.

In Harper's edited book, Hull (2000) wrote on the "processing of thermosets" where he described the industrial process of casting with liquid resins.

> "An example of liquid casting is in fabrication of design details such as scrolls and floral or leaf patterns for furniture decoration. Such parts are often made from filled polyester resins, and the parts, after curing, are simply glued to the wooden bureau drawer or mirror frame. The parts can readily be finished to look like wood. Moulds for such parts are often made by casting an elastomeric material over a wood or plastic model of the part. When the elastomer is removed, it generally yields a cavity enabling very faithful reproduction of the original pattern".

The above description is an elaborate explanation albeit industrially, the methods of modelling and casting in sculpture using fibre glass and resin. This shows the close affinity between engineering and sculpture and is just one of many examples of such cross-disciplinary approaches to production.

Hull also gave a description of the method of producing fibre-resin composites by what he termed "hand lay-up". This involved the use of a reinforcing fabric or mat; most often fibre glass. Such mats are placed over the mould, after which the mould has been prepared with an even application of a release film or separator and an initial resin gel coats. The methodically placed, mats are now superimposed with resin; ensuring little or no air pockets. Once the plastic hardens, it is removed from the mould trimmed and ready.

Hull lists boats, of various types, even military landing craft as products of this material and process.

In practice; 'modern plastics Handbook' is of relevance to this research to the extent that it gives a materials engineering background to the use and character of resin and fibre glass. It however re-iterates the already in use and popular method of working with epoxy resin and fibre glass which includes the liquid casting and hand lay-ups techniques. It is nonetheless silent on the technique which is of paramount to this research, which is direct modelling with fibre glass and resin.

Epoxy resins

Gannon and Brytus, (1990), described epoxy resins as thermosetting resins. Thermosets are solids that may become soft when heated but never return back to liquid states. This process is irreversible as a boiled egg can never return to the original liquid yoke.

This curing process takes place in two ways the first is known as catalytic reaction whereby the epoxy molecules react directly together in a process ignited by a catalyst. The second involves poly-addition which contains hardeners mixed into the resins.

Polyester resin and epoxy resins

They are both a category known as thermosets. Polyester resin is a kind of polymer. Both epoxy and polyester resins

require the addition of some type of reactors to initiate the process of curing. However, the major differences in both resins lie in their uses. While epoxy resins are useful in making such products like adhesives, casting, laminating, surface coatings, tooling, vinyl stabilizers etc. Polyester resins are employed mainly in such products like; trays, boats, shower stalls, swimming pools and water tanks, etc. some of the material qualities of polyester resins include flexibility, resilience, low shrinkage, weather proofs, chemical and fibre resistance.

Here are some of the differences between polyester and epoxy resins;

1. Polyester need catalyst for curing
2. Polyester is tolerant to temperature
2. It is cheaper than epoxy resin. (in Nigeria polyester resin costs about ₦3,500($7) per litre while epoxy cost about ₦8,000($11) per litre) (as at August 2023)
3. Polyester goes better with fibreglass while epoxy goes with carbon fibre
4. Epoxy is highly adhesive and is used in high specification products like aircrafts and boats.
5. Lastly, epoxy possesses higher structural strength.

Glass-Fibre

Imtaz, (2014) stated that glass is "a uniform amorphous solid material, usually produced when a suitable viscous molten material cools very rapidly.

Gotten from the Latin words "Glessum". Glass means a transparent, material that lustres. There are different types of glass: flat glass, blown glass, glass beads, special glass (as in optical fibres) container glass, fibre glass etc.

The basic components of common glass and fibre glass are silica (SiO_2) which is a combination of silicon and oxygen (silico dioxide). Silicon occurs naturally as sand.

The major difference between flat or common glass and fibre glass is in the rate at which the temperature s lowered after the compound has been melted. To make glass, the molten silicate of SiO_2 is cooled down so fast that the atoms of the silica are stopped from realizing in their organised crystalline structure in which it is naturally found. The randomisation of the silica structure gives glass as a product. However, in making fibre glass, the rate of temperature reduction is showed down to allow the atoms take back their crystalline arrangement.

Imtiaz (2014) described glass fibre as "a material consisting of extremely fine filaments of glass that are combined in yarn and woven into fabrics. According to him, the glass is heated to a molten state, after which it is forced through superfine holes, which gives filaments of glass which are so thin that they could only better measured in microns. On the history of fibre glass, imtiaz claims that the drawing of glass into fibres is an ancient technology (6000 years) which is older than the technology of glass blowing; an assertion which challenges the early held notion that Dale Kleist discovered fibre glass when he accidentally channelled a pressured air over molten glass around the early 1930s.

Imtiaz further validated the assertion by opining that Napoleons funeral coffin was decorated with glass fibre textiles.

Theoretical studies

This experimental study could be situated within Gottfried Semper's materials theory, as noted by Chestnova, (2018), Sempers theory of materials challenges the earlier popular design Canons by Pugin, Ruskin, and Viollet-Le-Ducj all 17th century theorists of architecture and the decorative arts. Temper in his propositions opined that new forms and interpretations could be realised and arrived at by designers through the careful study and appropriation of motifs and their subsequent translations into other new materials. According to him, no matter the new materials employed in the re-interpretations of an already existing motif, the essence and

traces of the motif is bound to be retained even in the new work as a form of composite and metamorphose form.

In his Magnum opus, put forward in 1860 Semper introduced a phenomenal idea that challenged the prevailing aesthetic attractiveness of the concept of "truth to material" which was popular in that era, encouraging exploration spirit among artists, and craftsmen to dive into the exploration of motifs and form using new and unfamiliar materials. This he did by establishing a historical/cultural precedence which as he acclaimed followed such example to arrive at harmonious and hybrid new forms with consistency in meaning and content. Titled "Stoffwechsel" he gave form to the idea in his magnum opus 'DeStil' describing it as follows ...

> When an artistic motif undergoes any kind of material treat, its original type would be modified, it would receive, so to speak, a specific colouring. The type is no longer in its primary stage of development but has undergone a more or less pronounced metamorphosis. If the motif undergoes a new change of material (Stoffwechsel) as a result of this secondary or even multiple transformation, the resulting new form would be a composite, one that expresses the primeval type and all the stages preceding the latest form.

The relationship between Semper's theory, and this study is not in the re-interpretation of motifs as expanded in part of his theory but rather, it is in the application of a sculpture material following a hitherto unfamiliar route or technique to arrive at a product with primeval affinity to the originating intended form. As Chestnova, (2018) puts it "it is human judgement and ingenuity that determine artistic forms for Semper, the relationship people build to things in the process of the making and their use, and not only properties inherent in the materials and the technique".

It is therefore this acclaimed ingenuity, human judgement relationship and usage that have motivated the researcher's approach as a route to the realization of the desired motif/form."

Empirical studies

In Harper's (2000) modern plastics handbook, we get a glimpse of what could be regarded as the story of the discovery of the use of resin polymer. According to Harper, the native Haitians were already using balls made from materials gotten from a tree. Christopher Columbus found the Haitians playing with these balls made from natural rubber in the 1400s. This forms the beginning or rather forerunner of the modern day plastics. The development of the use of rubber continued in an unprecedented speed with the discovery by Charles Goodyear that the addition of sulphur to the material improves its properties. However, it was until the early 1900s that the first true synthetic polymers were made, from the combination of phenol and formaldehyde. This was the foremost resin ever made; called the Bakelite. A trademarked synthetic resin invented in 1907 by Leo Hendrik Barkeland. Synthetic polymers are compounds made from the combination of simpler molecules of other elements coming together to from complex structures. It is synthetic because it is done by chemical manipulations/combinations which usually follow scientific procedures and methodology.

In the course of the last 4 decades, several artists and sculptors have embraced the use of fibre glass and resin composite as sculpting materials. As a result of this, several positive attributes of the material have been discovered and established, leading designers and artists to continue to consider too as a choice material for the projects.

Beerkens, and Breeder, (2012) while writing on the conservation of and production of outdoor sculpture made with Fibre Glass-Reinforced polyester noted that the medium is a new twentieth century material which though is strong and long lasting, it has its

own peculiar issues of "wear and deterioration" especially when used in outdoor sculptures.

Among the attributes mentioned by the writers as the main characters of the material are strength, easy workability, multiple colour choices, and most importantly, it makes it easy and possible for artists to produce the finished sculptures by themselves and on a desirable large scale too. This is so because unlike the more durable bronze, for example, which requires that sculptors engage the services of bronze casting professionals and foundries in bringing their designed works (which usually ends in clay) to a more durable and casting state, they could begin the art process and finish and finish same within the confines of their studio space without much external/professional consultations.

In a previous research by (Njoku, 2019), the behavioural attributes of fibre glass composite when exposed to the elements for a measured period of time was observed.

Although the study was chiefly concerned with the "production of mosaiculture and topiary art for environmental management and aesthetics in Nigeria" it involves the production of mixed media sculptures some of which involved the use of fibre glass composite for examples, the researcher used fibre glass and epoxy resin to coat the inner walls of bamboo stems used as flower planters in one of the works. Experimentally, the researcher established that when only epoxy resin is applied to the bamboo stems surfaces, they tend to peel off over a period of time (2 years). However, the inner walls which were sealed with a combination of epoxy resin and fibre glass remained intact even under constant watering and drying under the sun.

Beerkens, Stigter, Oosten, And Kuelen, (2008) wrote extensively on the performance of Mata Pan's 1961 fibreglass sculpture against the harsh weather conditions that surrounds it, and it mechanical parts that ensures its floatation in a pond within the premises of Kröller Müller Museum. Although the museum has been taking good care of the work, seeing to its periodic maintenance and restoration, the writers established that the work has not fared badly, notwithstanding the fact the several layers of chemicals and cocoon does not allow for the proper examination of the Fibreglass parent material.

As could be ascertained from the already reviewed literature, the character and behaviours of fibre glass and epoxy resin are quite known. It has been established too that they are best used as composites. The history of its discovery has also been noted. This research proceeded to experiment on a non-traditional approach to the used of fibre glass and epoxy resin in creating sculptural works, as little literature exists in such direction.

Of all the literatures reviewed for the purpose of this research, Newman, (1975) book; crafting with plastics gives the most resourceful information on the techniques of using and sculpting with polyester resin and fibre glass.

Newman was able to categorise polyester and epoxy resins as two different types of thermosetting liquid plastics with the only difference being that epoxies don't shrink so much when they harden (curing) as compared to polyester and they are also more expensive. The writer went further to identify other components that col be added to the resin in order for it to harden. The most important for this hardening reaction is catalyst. However, the regional country local availability of these materials varies, therefore, the chemicals obtainable in Nigerian market may not be exactly as is applied in Newman's book.

Another point of departure, is in the additives to the epoxy resin for curing. Newman writes that "when catalyst is added to the resin, a chemical reaction takes place that generates heat, thus causing the resin to harden", there is an addictive of a 3rd variable, the accelerator. This addictive, it is believed helps to speed up the rate of the reaction.

This research is able to prove that this rate could be measured by the difference in the amount of time required for the curing process when only catalyst is used and when accelerator is added to the mixture.

The assumption that epoxy resins are the reality resins in Nigeria local market notwithstanding, in Page 24 (Chapter 1) of Newman's books the writer emphasised, the need to play around with resin catalyst variations to lower exothermic creation, lower shrinkage, to change colour, to change speed of cure and to minimize sensitivity to the catalyst. Suggestions that were never given while he talked about mixing polyester resins. This leaves a question mark on his previous claim on the lesser shrinkage of epoxy resin when compared to polyester resin.

Also going further, Newman gave suggestions on the propos portions of resin/catalyst to be used for different desired casting thickness. For 100 grams of polyester resin he suggested about ¼-1/2 gram of catalyst (MEK Pentoxide)). However, for same amount of epoxy resin, he suggested between 20 to 25 grams of curing agents depending of the brand of catalyst used. This also points in the direction of the fact that the type of resin used or found in Nigeria local market is the polyester resin considering the fact that it requires minimal amount of catalyst for curing than epoxy resin.

Establishing what variety of resin widely used in Nigeria is not really the concern of this research, but literature reviewed, especially Newman, (1975) book has established that there are at least 2 different varieties in Nigeria. Newman also rightly opined that when polyester and epoxy resins are used to reinforce fibre glass, it is widely used in industries to produce cars, boats, furniture, storage, tank and so on; noting that this is done usually by laying cut out pieces of fibre on moulds and using brittle brushes to impregnate the fibre glass with the catalysed polyester resin. This processed the enhanced using a fibre glass, and polyester spraying gun which evenly distributes the composite into the negative mould simultaneously. Lastly, Newman, anticipated this present research while conceded that it is possible to apply fibre glass reinforced polyester or epoxy by laying strips of it by hand over moulds or in moulds (called hand lay-ups), or over armatures. This present research has therefore taken this single paragraph up, to develop it into a recorded experience with noteworthy discoveries.

Production Process of Sculpture

The first step in making every sculpture piece begins with the conceptualising of the idea which would be brought to reality through the materials and methods of sculpture. This conception begins in the mind, at this point the sculptor develops a mental picture of that he intends to create. This is most applicable where the desired/visualized work is such that is conceptual or non-representation to make drawings and sketches of what is intended, followed by the making of Marquette or miniature version of the sculpture. It is from the miniature that the big or life size sculpture would be realized using the former as study reference.

These initial processes notwithstanding, the present research being concerned not just with the exploration of direct modelling with fibre glass composite as a techniques of sculpting, but also finish sculpting piece at a record time. Therefore, the above listed steps were jumped.

Kysar, (2001) Suggested this stage makes the first step in sculpture production.

Production of the Two Horses

1st Stage

Armature construction

For reference purpose on the anatomy of horses, Henderson, (2000) book on horses was consulted. With this, the sculptor made due with the photographs as working drawings and for study.

Using the photos, the sculptor produced, metal armature by arc welding. Using 8 mm metal rods and quarter rods, the sculptor aimed at building the forms of the two horses as closest to naturalism as possible. Also 2 inches angle bars were used to form a rectangular base on which the horses' armature stood. This was to ensure stability and facilitate the easy installation of the works.

Covering with mesh

Once the armature construction is done and the figure is rendered satisfactorily in metal, the sculptor proceeded to cover the surface areas of the two horses with mesh. The 1.5mm holes mesh is secured to the body of the armature with bindings wires. At this point the sculpture appears more solid and the clearer view of what the work would look like when finished could be observed. (see plate 1 and 2)

Fibre glass/resin casting

At this stage, the horses are no covered with impregnated fibre glass mats. To begin, rolls of fibre mats are cut to about 1 feet square or lies depending on the area of the armature to be covered and the intricacy of the forms. Most times the fibre mats could be separated transversely to reveal 3 layers of mats, ad each could be used separately to reveal 3 layers of mat, an each could be used separately peer area depending on the desired thickness of the cast. However, the sculptor chose to use the mat wholly without separating the layers (this was to ensure a solid and rigid cast). This required however, that the mats are squeezed with hands before spreading on the armature. This facilitates easy penetration/impregnation with the polyester resin mixture.

Once the mat is laid upon the armature, the resin which has been added a proportionate amount of catalyst and accelerators is generously applied over the work using brittle brushes. This procedure is repeated continuously until every point of the horses is casted. The work is subsequently allowed to cure. Curing takes between 30 minutes to 1 hour to complete.

Filling and modelling with calcium

As soon as the fibre glass composite cast is cured, the work is ready for further fine turning. One noticeable future of the work at this stage is the presence of jagged tactile areas across the sculpture forms. Trying to feel the surface of the sculpture at this stage is bit hazardous as the already hard fibre glass spikes are ever more deadly at this point. One hardened the fibres assume a natural pin-like character that punctures and crutches everything that rubs against it.

Therefore, to begin the next stage of modelling, the sculptor proceeds by using angle grinder flitted with sounding paper to smoothen the surface areas. This ensures that the forms are evenly viewed and the sculptor could safely feel the undulations that requires fill up.

Also, some intricate parts of the sculpture that could not be properly rendered during the fibre casting could now be modelled. The main ingredient for this modelling is paste formed by the mixture of polyester resin and calcium carbonate CaCo3. The latter is a powdery substance usually white or grey in colour.

To form the paste, a desired quality of resin is poured into a container, a proportionate quantity of accelerator is added and the mixture is stirred. Then gradually, a handful quantity of CaCo3 is poured into the mixture and is continuously stirred until the desired consistency is achieved. The consistency is such that it could be used to model a form and it stands without it wobbling.

With this paste, the sculptor attempts to fill up the observed undulations and other noticeable holes and crevices, as well as to create some intricate forms such as the eyes, noses, ears, and the tails. (see plate 3)

Note that for the calcium/resin paste to harden when applied the sculptor dips the paste into catalyst each time he scoops such

from the container, rolls it over with the fingers, ensuring that the catalyst is thoroughly applied before it applied over the work piece.

Finishing stage

After the surface of the sculpture has been filled to achieve the desired forms, the sculptor goes on to sand the whole work using angle grinder and sandpaper. After filling, the horses are covered with a base paint (primer). This priming helps the sculptor to see any further blemishes on the work as the work now has an even hue. Using spraying machine, every part of the sculptures is now painted with the chosen colour (brawn) and the work is ready. (see plate 4)

Results and Discussion

These are some of the research findings:

After the first stage of covering over the armature with chicken mesh, there were lots of depressions that could have been covered further with mesh before fibreglass casting is initiated, this would have eliminated many of the depressions noticed after the application of primer. Although effort was made to fill them up with calcium paste, getting it right at the armature stage would have ensured the forms came out better.

One of the notable findings of this experiment is the fact that the quantity of resin that is lost during the casting stage is equivalent to 1/3 of the sum of the quantity of resin used in the whole work. Therefore, establishing that this technique is not economical when compared to the traditional casting technique.

However, one advantage of the direct casting technique is the harmonising of the armature into the main body of the work, this gives the sculpture more structural strength and is expected to make the work last longer and better suited to withstand external pressure than works cast without internal armature.

Although this technique is faster, more precision is required in order to apply it. (It takes an average of between 3 to 4 weeks for the researcher to model and cast a sculpture of same size as the case study, while the current experiment took a week and 4 days to execute)

For best results and easy manipulation of forms, this technique of sculpting would be most ideal when working on sculptures that are designed with simplified geometric planes, this is so considering that fibreglass flows better when there are less surface undulations.

From the results of the research as seen in plate 4, the research objectives could be said to have been met. The sculptor successfully produced and recorded the production processes of two life-size horse (adult and foal) using fibre-glass direct modelling technique. Because there isn't so much literature on using direct modelling with fibreglass for sculpture production, one could only compare the current research with literatures on the traditional sculpting techniques. One of such could be found in the work of Emeribe, (2020). Empirically, his work agrees with the current research in areas such as the ratio of resin, catalyst, and accelerator combinations during casting. However, his working methodology deferred since he used the traditional method of casting from mould.

Through this research, the sculptor has been able to put into records (written) the working methodology on direct modelling with fibre glass. Being a new technique within the researcher's immediate environment.

Conclusion

The two horses took 2 weeks to be sculpted; from armature stage to the finishing stage. On the average, this is a far less time to spend on a sculpture project of such magnitude; this is not however without other challenges, such as the wastage of resin that drips on the floor during casting, and the need for intermittent recording of each stage of the technique using

camera and note taking. This is a major limitation of the study considering the absence of a research assistant and the delays that follow. However, these delays could be discountenanced since it is incomparable to the amount of time spent while working with the traditional methodology of armature construction, clay modelling, mould taking, fibreglass casting, joining, and finishing.

However, the study being a studio experimental work, did not employ lots of scientific investigative apparatus and therefore, still requires further clinical scientific research, this could be as it concerns sustainability, and durability of works produced using the direct fibreglass modelling and casting technique. In essence, direct fibreglass modelled and cast products could be subjected to the research conducted by Stamatakis *et al.* (2010) as seen in the review of related literature.

The study could help other sculptors who wish to employ the same technique, to understand how it works and how to avoid the challenges. This is even more relevant considering that the study could be made available to students in sculpture unit of the Department of Fine and Applied Arts of Nnamdi Azikiwe University, Awka, as the immediate beneficiaries.

Beyond sculpture making, the technique in view could be utilized in making other industrial products such as boats, auto-parts, building materials and other products requiring impact resistant qualities.

Limitations

One major challenging factor which the researcher battled with in the course of this study was the strict devotion of time for the production of the two horses. This is because since there was the need to compare the differences in the times for using this technique, the writer had to consciously make effort to note the time spent on the work as compared to time spent while employing the traditional modelling and casting technique.

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Appendix



Plate 1: Armature of the foal covered with metal mesh. (Njoku, 2019)



Plate 2: Armature of the horse covered with metal mesh. (Njoku, 2019)



Plate3: Modelling and filling with calcium paste. (Njoku, 2019)



Plate 4: The finished horses (Njoku, 2019)