INVESTIGATIONS OF DIRECT SUNLIGHT CURING OVER ARTIFICIAL UV CURING OF COMPOSITES FOR STRUCTURAL APPLICATIONS.

A PROJECT REPORT

submitted by

FEBIN GEO SAM

TKM20MECI04

to

the APJ Abdul Kalam Technological University

in partial fulfillment of the requirements for the award of the Degree

of

Master of Technology

In

Computer Integrated Manufacturing.

Department of Mechanical Engineering

TKM College of Engineering

Kollam

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DECLARATION

I, Febin Geo Sam, hereby declare that the project report "Investigations of Direct Sunlight Curing Over Artificial UV Curing of Composites for Structural Applications." submitted for partial fulfillment of the requirements for the award of degree of Master of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of Dr. Mubarak Ali, Assistant Professor, Department of Mechanical Engineering, TKM College of Engineering, Kollam. This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

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CERTIFICATE

This is to certify that the report entitled '**INVESTIGATIONS OF DIRECT SUNLIGHT CURING OVER ARTIFICIAL UV CURING OF COMPOSITES FOR STRUCTURAL APPLICATIONS**' submitted by '**FEBIN GEO SAM (TKM20MECI04)'** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Computer Integrated Manufacturing, Mechanical Engineering is a bonafide record of the project work carried out by him under my guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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ABSTRACT

Current world scenarios demand the need of making fabrication more sustainable with renewable energy sources as it plays a vital role in global sustainability. The technological and scientific advancement along with population growth in exponential rate demands more electricity and the production of energy is slighter as per demand put forward by the vast population which leads a massive power crisis in all over the world especially developing nations like India. The area of composites has obtained great application interest in a number of predominant fields from consumer products to aerospace. Hence lot of energy is utilized from non-renewable sources to fabricate the enormous number of composites. Utilization of renewable source of energy in fabrication of materials will result in a decreasing energy demand. The sustainable power or energy sources are hypothetical approaches to produce energy from everlasting limitless standard assets. Sun, the everlasting source of light is renewable energy source which consists of ultraviolet rays, infrared rays and visible light rays. Curing of fiber reinforced in light sensitive photopolymer composites is usually done with the aid of UV sources. An investigation of curing the above-mentioned type of composite with the help of UV from direct Sunlight is carried out in this study. Sunlight curing of composites will help to explore its usefulness as a sustainable, renewable as well as cost-effective production technique without unacceptable sacrifices of mechanical properties. This technique will eventually reduce a vast amount on energy demand and can be considered as a sustainable technique.

Keywords: Photopolymer resin, UV curing, Sunlight curing, Energy Sustainability

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ABBREVIATIONS

UV	–	Ultraviolet
PMC	–	Polymer Matrix Composites
CMC	–	Ceramic Matrix Composites
MMC	–	Metal Matrix Composites
FDI	–	Foreign Direct Investment
US	–	United States
PSR	–	Particle Size Ratio
UVR	–	Ultraviolet Region
GFRP	–	Glass Fibre Reinforced Polymer
GFRPP	–	Glass Fibre Reinforced Photopolymer
A glass	–	Alkali Glass
C glass	–	Chemical Glass
D glass	–	Dielectric Glass
E Glass	–	Electrical Glass
S Glass	–	Strength Glass
AE Glass	–	Alkali and Electrical Glass
ECR Glass	–	Electrical and Chemical Resistant Glass
LED	–	Light Emitting Diode
Ra	–	Arithmetic Mean of Roughness
Rq	–	Root Mean Square Value of Roughness
Rz	–	Roughness Depth Value
ASTM	–	American Society for Testing and Materials

NOTATIONS

L	–	Centimetre, cm
M	–	Mass, g
R	–	Roughness, µm
T	–	Temperature, °C
V	–	Volume, cm^3

Greek Symbols

ρ	–	Density, g/cm^3
σ	–	Tensile strength, Mpa

CHAPTER 1

INTRODUCTION

Current world scenarios show the need of making fabrication more sustainable as it plays a vital role in global sustainability. Energy shortage is a predominant bottleneck in the supply of energy resources to an economy. Most energy crises have been caused by manufacturing industry, localized shortages and market manipulation. Lot of nonrenewable energy is utilized for the fabrication in the field of materials. Material is substance that constitutes an object. An electricity shortage is felt most acutely in day-to-day needs. Therefore, a sustained energy crisis eventually results in a huge humanitarian crisis. The technological and scientific advancement along with population growth in exponential rate demands more electricity and the production of energy is slighter as per demand put forward by the vast population which leads a massive power crisis in all over the world especially developing nations like India.

Utilization of renewable source of energy in fabrication of materials will result in a decreasing energy demand. The sustainable power or energy sources are hypothetical approaches to produce energy from everlasting limitless standard assets. These everlasting assets are either accessible without time constraints or renewed more rapidly than the rate at which they are utilized for needs. Recently, the country India witnessing massive power shortage due to elevated demand by the big population and unavailability of adequate suppliers of coal. More than hundred million units of power shortage experienced during the months of March, April, May of 2022. North Indian states such as Rajasthan, Gujarat, Haryana, Delhi, Punjab, UP, Bihar and MP were the most affected states than southern states.

The recent demand noted for energy/power is barely a little over half of countries total installed energy/power generation capability of approximately 400 Gigawatt. However, due to the unavailability of exhausting coal supplies this energy shortage are witnessed. The paucity of coal supply occurs almost all year and despite various calculations, India is not yet all succeeded in overcoming this never-ending problem. To address this never-ending issue of underlying shortage in power/energy and structural mechanical problems are need to be short sorted out and for the same the solution is to make sure of set upping the renewable power plants.

The inexhaustible sustainable power or energy sources are talked about rather than exhaustible petroleum derivative sources of energies. The petroleum product's stocks are controlled and non-sustainable in relation to human timescale. The most known instances of these exhausting energy assets are in form of coal, oil or gaseous petrol. On the spur of the moment, everlasting sustainable power sources are delivered from inexhaustible sources. The energy coming from sunlight-based waves, winds or even the water cycles – all hypothetically not dependent and everlasting to human scale time. Various types of demanding renewable energies are put forwarded by different eternal sources such as the sun, wind or water. This never-ending renewable source's power consumption has been exponentially growing over the last few decades particularly last few years. Solar energy is eternal in the right sense that it will cease once the solar system dies.

In 1987, the World Commission on Environment and Development made this idea widely accepted. According to their research, the concept is "growth that satisfies present wants without endangering the capacity of future generations to satiate their needs." In other words, they sought to stop the natural world from being deprived of the resources that future generations will need. We are well aware that a single requirement typically propels progress. As a result, the longer-term effects are not taken into account. This type of strategy thus causes a lot of harm. Therefore, the repercussions will be increasingly severe the longer we pursue unsustainable development. Climate change is one of the most prevalent, and it is a topic of intense debate on a global scale. Advocating the use of unconventional energy sources, particularly solar energy. It will be helpful to look for alternatives to known toxic products based on the needs and resources of the local area. We also need to create environmentally friendly items. Sustainable Development is one of the most contentious and pressing concerns of our day and is quickly becoming essential. Humans have relentlessly pursued modernisation while frequently compromising with the requirements of a greener earth. As a result, the prevalence of deforestation, pollution, greenhouse gases, climate change, etc. makes the rising environmental degradation obvious. Due to the debate surrounding large dams and megaprojects, as well as the ensuing long-term expansion, the idea of sustainable development in India is even more important.

A composite material is a distinctive structural material developed by fusing two or more fundamental components. When compared to the individual materials employed in it, these materials have better mechanical and material qualities. The finished product will be distinctive, strong, and lightweight. As a result, these materials are very commonly employed in many different applications, including those involving buildings, railways, aviation, electricity, and healthcare. Recent developments in these areas have led to structures for satellites and spacecraft, among other aerospace uses. These materials are more flexible in terms of design and have fewer maintenance costs. Consequently, it is simple to produce any intricate shapes.

As per the type of matrix material employed, composite materials are typically categorized as The Polymer matrix composites (PMC), The Metal matrix composites (MMC), The Ceramic matrix composites (CMC), Composites made of carbon and carbon. One of the most widely utilized and predominantly developed advanced composite materials is polymer matrix composites.

The area of fiber reinforced polymer composites as a material has obtained great application interest in a number of predominant fields such as aerospace engineering, wind energy, automotive industry, infrastructure fields, and even in consumer applications. Metals have been substituted in some applications by fiber composites such as glass reinforced plastic (glass fiber) and carbon fiber reinforced polymers. They are not fatigued and are lighter than metals. Glass fiber is used to make some automotive bodywork.

Due to its light weight, which improves acceleration and fuel input but is less durable than steel of the same width, it offers less protection to the driver and passengers. Glass fiber does not rust like metals, making it ideal for usage like boat structures. Glass fiber is ideally suited for minesweepers since it is nonmagnetic. Greater varieties of curing methodology are keenly investigated to develop the lower cost and high energy efficient fabrication technique of polymer composites. But it still remains as a greater challenge and thorny issue. Especially, the autoclave curing process, which is world widely used for the curing of structurally high-performance polymer composites, is capital intensive, with costs increasing exponentially with size and limiting the use of polymer composites. Researchers and industrial experts are interested to explore and develop thriftier and highly efficient curing methods for the fabrication of polymer composites and investigated different radiation and thermal curing alternatives. The current development status of the radiation curing techniques including gamma ray, x-ray, ultraviolet, accelerated electron beams and thermal curing techniques which includes radiation warming, convection and conduction heat warming, heating by induction, heating by ultrasonic, heating via resistance and thermal additives-based methods applied for the curing of advanced polymer composites. These methods are selected according to the material, availability, feasibility, cost and power variabilities for successful curing application of polymer composites.

Polymer consist a very vast molecule structure comprising millions of atoms formed by successive linking/bondage of one or two, occasionally more, types of small molecule in chain or network structures. Photopolymers are advanced light sensitive polymer resins. They are very sensitive to light and cure independently with the aid of light. Sun, the everlasting source of light is renewable energy source which consists of ultraviolet rays, infrared rays and visible light rays. Curing of fiber reinforced in photopolymer composites can be done in sunlight. This technique will eventually reduce a vast amount on energy demand and can be considered as a sustainable technique.

Due to the factors such as ease of fabrication, high stiffness-to-weight and strength-to-excellent fatigue, mass ratio and performance in corrosion, glass fiber-reinforced polymer composite materials, have demonstrated superior advantages with advanced performance at decreased weight over more conventional metallic materials, in almost all applications. Recently, applicability of advanced photopolymer composites for a variety of huge and complex structural parts and structures are becoming reality. Polymer composites are widely used for the manufacturing of a great variety of advanced products for various applications including medical, defence, wind energy, sports, automotive and space technologies. Ongoing and published researches on UV curing and influence of the several parameters on the properties of cured composites have greater demand in the field of materials. But UV cured composites based on glass fibre reinforced light sensitive photopolymer resins are yet to be addressed and developed.

CHAPTER 2

LITERATURE REVIEW

A manufacturing industry transform raw components to consumer goods. Population explosion and urbanisation resulted an elevation in consumer demand for products. For transformation of raw to product, industries need sizeable amount of energy. The manufacturing industry is one of the main sources of energy consumption. Source and utilization of energy is a high valued variable controlling overall economy of our country [1-3].

Developing countries promotes sustainable energy consumptions practices to attract developed countries foreign direct investment (FDI) aimed at inflows of technology transfer. Over the past few decades, India's growth rate has been rising positively. As a result, the Indian government has implemented a number of energy measures to a sustainable energy supply that can satisfy the needs of the country future without any limitations. Naturally, rapid economic growth in the nation also produced a significant amount of carbon. India is now the third-largest emitter of carbon dioxide at a global scale as of late. [4-5].

The economic growth achieved by India is majorly driven by continuous energy consumption. In order to keep the production units running, import of extra non-renewable energy sources increased to meet the extra demand. India could pursue energy conservation and energy efficiency since the majority of its fossil fuel consumption is focused on the use of coal. without sacrificing long-term income growth. This is how India is able to reduce CO_2 emissions, a major greenhouse gas accountable for climate instability, economic imbalance, unsustainability and global warming [6-7].

Whenever we investigate India's growth trend, we can observe that energy consumption is a crucial factor in the country's economic success. India is one among the world's net importers of crude oil among emerging countries, primarily due to the needs of the industrial sector. India's imports of crude oil increased by 81.27 percent between 2008 and 2014, coupled with the rise in the US Dollar's foreign exchange rate by 40.18%. due to poor regulation of industry and India’s captive power plants are turning to the energy trade market for their supply of coal [8-9].

There are many sources of renewable energy sources available which is yet to be tapped for the increasing human’s energy demand. Renewable sources of energy have the ability to replenish themselves without other aids instead of being depleted in the earth. The main sources of renewable energies include solar energy, bioenergy, hydropower, geothermal energy, wind energy, tide and wave energy [10-11].

Solar energy is predominant among them. The total sum of energy from sun radiation falling on earth is sufficient to meet all the demand. It is actually thousands of times more than the actual demand [12]. The total insolation emitted from the huge Sun, approximately 50%, 40%, 10% lies in the infrared, visible and UV regions respectively [13-14].

Ultraviolet region is again classified into three types on the basis of their energy levels. Those are type A ultraviolet radiations, type B ultraviolet radiations and type C ultraviolet radiations. All of these radiations have specified roles in satisfying human needs. The type A ultraviolet radiations having higher wavelength is used as a curing agent in ultraviolet curing technique for composite manufacturing. Type A ultraviolet radiation is a long wave ultraviolet radiation comparing with other types of ultraviolet radiations such as type B and type C. Hence it is used to cure the deepest layers and provides adhesion by cross linking mechanism in photo sensitive resins [15-17].

A suitable methodology for curing mechanism is adopted on the basis of the certain variables. Those variables are availability of materials, end applicability, complexity in handling, factor of controllability, capability in penetration on deepest layers of polymer matrices and reinforcements taken and ultimately the cost incur on investment on equipment's, running of operations and maintenance provided. UV-curing is considered as thriftier, energy-saving, sustainable and user friendly compared to other types of fabrication methodologies [18].

The technical features of light sensitive resins cured by ultraviolet curing mechanism is determined by density of cross linkages. The cross-linking density depends on variables such as the proportion and type of the light sensitive photo initiators in the resin [19]. The cross-linking of this advanced resin is also depended on the light intensity, exposure and time period. The structural behaviors of the composites are strongly dependent upon the variables such as chemical and rheological events occurring during the cycle of curing. Cycle time of the ultraviolet curing mechanism is very much slighter as well as the power consumption is fewer [20].

While fabricating the sample, both the time of exposure and pressure of compaction affect the fibre content of composites and interlaminar shear strength between them. The elevated interlaminar shear strength is due to the force exerted in compaction increased the resin infiltration between adjacent layers of reinforcements [21].

Research on reinforcing composites with dual fibres for structural applications has sizeable value. The strength of such hybrid composite sample fabricated has increased considerably which consists of Kevlar and graphene as reinforcements. Strength has elevated and load carrying capacity of the material has also improved by reinforcing the composite with multiple fibres. So advanced composite materials have sizeable value in the field of material science. It is feasible to achieve composite materials with low heat-resistant reinforcing components including wood flakes, hemp, cotton, and flax as well as highly orientated resins services at affordable polymerization temperature and high re sin hardening rate [22].

Effects of photo-polymerization variables on determining composite hardness have direct relation. Camphor quinone is a routine photo-absorbing compound used in the field of advanced dental composite materials. This component absorbs energy near ultraviolet spectrum. The greater the amount of photon particles striking this composite material, the greater the amount of camphor quinone compound will be raised to the excited state. As potency in intensity of the light energy elevated more photons will punch the material. Hence, intensity is the key variable to the extent and rate of the polymerization process in the composite material [23].

Matrix produced of photo-crosslinked resins filled with various types of natural or highly oriented thermoplastics fibers results in development of new family of advanced composite materials. While comparing composite samples of photocurable resins reinforced with natural fibers and conventional fibers, the obtained products show improved properties. Hence photocurable resins have sizeable opportunity in area of composite materials. A powerful way to turn a liquid into an oil-based polymer quickly and effectively in the illuminated area is light-induced polymerization of multifunctional monomers. The reaction can be conveniently followed using real-time infrared photocopy, a method that records the immediate evolution of the time curve in a photochemical reaction that is undergoing ultraviolet curing [24].

Utilizing epoxy resin as the matrix material and E-glass fiber as the reinforcement, a fiber glass reinforced polymer was created using the hand-laying method. By altering the weight percentage (wt%) addition of the reinforcement to the epoxy resin as follows: 10 percent, 20 percent, 30 percent, 40 percent, and 50 percent, several sets of the composite were created. The resulting polymeric composite was put through a variety of mechanical property testing, including hardness, tensile, and impact tests. It was found that composites with various weight fractions of glass fiber had greater values for the mechanical qualities of hardness, tensile strength, and impact strength than epoxy resin that wasn't reinforced. Additionally, it was discovered that the values of those mechanical qualities grew in direct proportion to the weight percentage of reinforcement in the composites, with the composite with 50% of the reinforcement hold the biggest values [25].

Composite materials can readily be hardened by laser irradiation technology in ultraviolet-curable resins stuffed with fibers at normal surrounding temperatures. The architecture of crosslinking between components is based on the variables related to photo initiators. Bright prospects of radiation curing are a key to upcoming developments. The uniformity in curing will improve gradually with the dose of exposure elevation. The fundamental element controlling the homogeneity of the reinforcement particle distribution in composites produced using the powder metallurgy approach is the matrix to reinforcement particle size ratio (PSR) [26].

The application of reinforcements with greater average particle sizes will increase the homogeneity of the distribution. The mechanical characteristics also deteriorate when the reinforcing particle size grows as a result of slower work hardening and faster damage accumulation rates. In order to get the best performance, the microstructure must be optimized between smaller reinforcement particle size and more uniform spatial distribution. UVR has some beneficial effects, but it also has harmful effects that could be fatal [27].

The effect of the UV curing kinetics on the mechanical properties of vinyl ester composites manufactured by out of die UV cured pultrusion. The GFRP composites are very much responsive to variations of the UV curing technique. The increment of photo initiator combined with the resin has led to a faster UV curing kinetics. Pressure is applied along with fabrication to eradicate the presence of voids in GFRP composites which induces a reduction of all the mechanical properties [28].

Research work on direct sunlight curing of advanced composites with highly oriented glass fibres on light sensitive photopolymer matrices for structural applications will deploy sizeable contribution to the field of sustainable fabrication methodologies. Concentrating on sun for power tapping is a proven renewable energy technique and has the potential in every aspect to become cost-effective in the upcoming decades. Switching to renewable resources can effectively reduce climate change, but it must be sustainable in order to secure a sustainable future for future generations to supply them with energy. [29-33].

Our routine survival depends on energy to boost human development, which in turn promotes productivity and economic growth. There is still a paucity of renewable energy in particular. The paper's objective was to determine whether renewable the transition from fossil fuel-based to renewable energy sources was sustainable, and energy sources would alleviate the effects of climate change [34-38]. The Fabrication aided by the energy extracted from direct sunlight radiation helps to explore its usefulness as a sustainable, renewable as well as cost-effective production technique without unacceptable sacrifices of mechanical properties as well as structural properties.

2.1 PROBLEM STATEMENT

- The area of composites has obtained predominant application interest in a number of predominant fields from consumer products to aerospace. Hence lot of energy is utilized from non-renewable sources to fabricate the enormous number of composites. Sunlight curing of composites may help to explore its usefulness as a sustainable, renewable as well as cost-effective production technique without unacceptable sacrifices of mechanical properties.

2.2 SCOPE OF PROJECT

Energy shortage and its deficiency is a predominant bottleneck in the supply of energy resources to an economy of a nation. Lion share of the energy crises have been caused by manufacturing industry, localized shortages and market manipulation. Lot of nonrenewable energy is utilized for the fabrication in the field of materials.

Utilization of eternal renewable source for energy in fabrication of materials will result in a decreasing energy demand. If a material can be fabricated fully with the help of everlasting renewable energies, then it will revolutionize the current market.

Judging by recent and anticipated developments, radiation therapy appears to have intriguing futures. With the creation of ever-performing photo-polymer systems, more advancements are anticipated, resulting in the expansion of this cutting-edge technology into an increasing number of industrial sectors.

UV curing can be a gamechanger in the localized fabrication techniques available for composite material fabrications. While the direct sunlight curing may find its applicability in structural engineering applications where we can cure the material after it is applied for function.

2.3 OBJECTIVES

The following are the objectives of this investigative experimental study:

- To fabrication of GFRP composites with photopolymer.
- To cure composites using direct sunlight.
- To setup artificial UV illumination.
- To cure composites using artificial UV source.
- To investigate the material properties.
- To do comparative analysis.

CHAPTER 3

METHODOLOGY

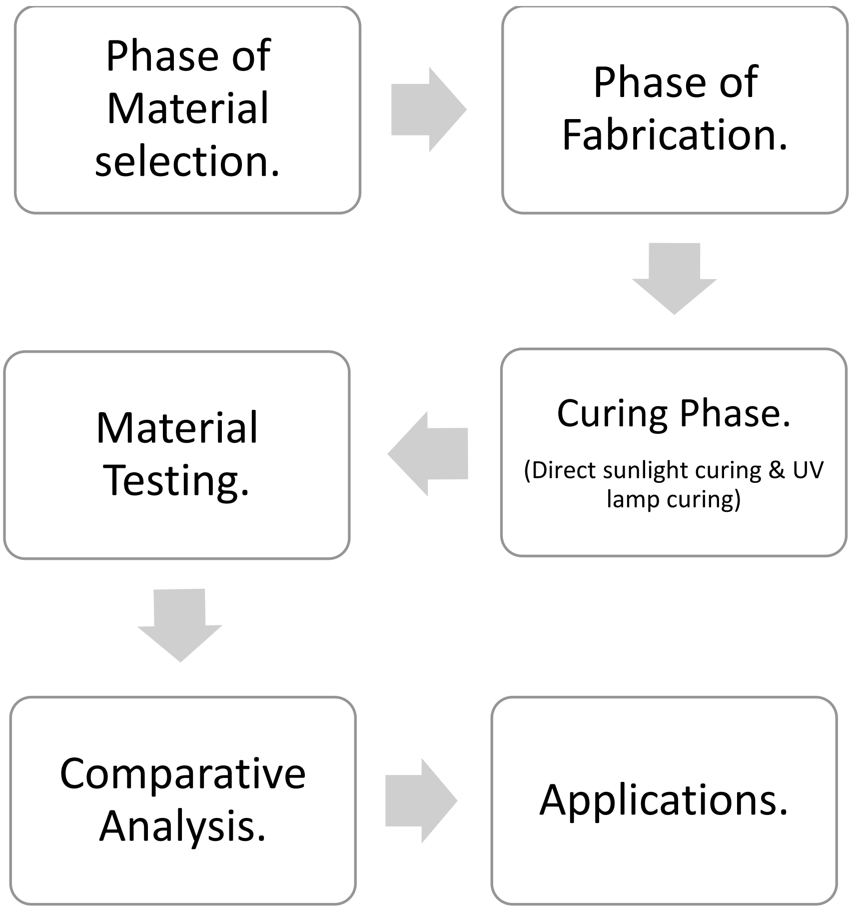

Fig.3.1 Flowchart of methodology.

The exertion starts with the phase of material selection. Proper materials are identified from a library of materials. The order of material takes place in this phase. Phase of fabrication will be initiated just after the first phase. In this phase the GFRPP composites is fabricated for both direct sunlight curing, artificial UV curing and testing. UV illuminating box is also developed in this phase for artificial UV curing. While in curing phase, the fabricated samples are cured separately in Direct UV and artificial UV rays.

After visual inspection, the samples are packed for testing and tested in laboratory in material testing phase. The result values are compared in this stage and analysed in the consecutive phase. Comparative analysis will answer the exertions carried out in this work and a proper area is identified from the results where this novel GFRPP composite can be replaced.

3.1 PHASE OF MATERIAL SELECTION

The phase of material selection consists of identifying the proper reinforcement and photo resin which is compatible with the proposed direct sunlight curing technique. A resin produced by a Korean company with trademark name FLORA BL50 is identified as the superior photo resin available in the market. So, FLORA BL50 is selected as the material for developing as continuous phase material in composite to be fabricated.

Fig.3.2 Ordered Glass fibre roll.

Currently, the fibres of glass contribute the preponderance of the discontinuous reinforcements most employed for the advanced composite materials in various application fields. The reinforcement taken here is glass fibers. Glass fibers can be broadly categorized into different forms such as A-glass, C-glass, E-glass, S-glass, etc.

The following classification is recognised for the glass used as a raw material to create glass fibres or nonwovens made of glass fibres:

Table 3.1 Types of glasses.

Major types of Glass fibres.	Peculiarities
A-glass	Alkali glass, Composition similar to window glass.
C-glass	Resistance to chemical impact.
D-glass	Thermal shock resistant.
E-glass	Electrical insulator.
AE-glass	Alkali resistant glass.
ECR-glass	Waterproofing glass.
S-glass	Glass having good Structural properties.

Each of which is used for specialized applications. S-type glass fibres of bidirectionally woven with minimum grams per square meter is selected. Fiberglass is yet another name for glass fibre. It is a substance created from incredibly fine glass fibres. Fiberglass is a strong, lightweight, and durable material. Although it is less stiff and has slightly lower strength than carbon fibre, the material is often much less brittle, and the cost of the raw materials is significantly lower. When compared to metals, its bulk strength and weight characteristics are also quite beneficial, and it can be easily manufactured utilising moulding procedures. The earliest and most well-known performance fibre is glass. Glass has been used to make fibres since the 1930s. The four main classes of glass fibres are used in goods such as chopped strands, direct pull roving, assembled roving, and mat products. Hence S type glass fibres of bidirectionally woven with minimum grams per square meter is preferred and selected as the accurate reinforcement for the novel composite material to be made.

Table 3.2 Different types of glass fibres and properties

Glass type	% Of SiO_2	Density (g/cm^3)	Tensile strength (Mpa)	Modulus (Mpa)	Elongation at break (%)
S glass	64-65	2.53	4600	89	5.2
A glass	63-72	2.44	3300	72	4.8
E glass	52-56	2.54	3448	72	4.7
C glass	64-68	2.56	3300	69	4.8

3.1.1 Materials Required in Fabrication.

- Glass mould.
- Cleaning agents such as Acetone.
- Peel ply.
- Scissors.
- Cello tape.
- Roller brush.
- Wiping tool.
- S type Glass fibre.
- Light sensitive photopolymer resin.
- UV lamp
- UV cabin box

Fig.3.3 Glass fibre used as reinforcement.

Fig.3.4 Photopolymer Resin used as continuous phase.

3.2 PHASE OF FABRICATION

In the phase of fabrication, a suitable technique from a list of composite manufacturing technologies is picked based on the compatibility with selected type of advanced resin and reinforcement. Hand layup technique is selected due to controllability and compatibility reasons with direct curing with sunlight.

3.2.1 Hand Layup Method

Hand layup technique is executed by considering variables such as controllability, compatibility and efficiency in fabrication. Curing practices for the fabrication of advanced composites is of significant academic and industrial interest. Prepreg, a type of reinforcement, is manually laid down in individual layers or "plies" during the production process known as "hand layup." This is made up of many fibers that have been pre-impregnated with resin, bundled into tows, and either bidirectionally woven together or organized in a single unidirectional ply.

Multiple materials are combined to create composite materials, which have extraordinarily high specific weight and stiffness properties while maintaining a light weight for the item. A discontinuous strong reinforcement and a continuous matrix make up a composite. Epoxies and polyesters are two of the most widely used matrices. Composite components are distinctive in that they can be made to withstand loads coming from a particular direction.

The Hand lay-up technique is one of the foremost methods of composite material processing technique. The infrastructural requirement for this method is also very minimal. The processing steps are quite easy. First of all, a release gel or wax is sprayed on the mould surface to remove the sticking of light sensitive photopolymer resin to the surface. Glass fibre Reinforcement in the form of woven mats or chopped strand mats are cut as per the mould size and placed at the surface of mould after. Then photopolymer in liquid form is poured onto the surface of mat already placed in the mould. The polymer is uniformly spread with the aid of brush. Consecutive layers of mats are then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required number of layers are stacked. After curing either at sunlight or at some specialised UV lamps, mould is opened and the developed composite part is taken out and further processed.

The simplest way for processing composites is hand lay-up. This strategy requires little in the way of infrastructure. The procedures in the processing are really basic. To prevent polymer from adhering to the surface of the mould, a release gel is first sprayed on it. Cut to fit the size of the mould, reinforcement is then positioned on top of the mould in the form of woven mats or chopped strand mats. The liquid thermosetting polymer is then completely combined with the recommended hardener (curing agent) in the proper proportion and poured onto the surface of the mat that has already been placed in the mould. A brush is used to spread the polymer evenly. Then, consecutive layers are added. After the curing phase either at room temperature or at some specific determined temperature, mould is opened and the developed composite part is taken out and further processed.

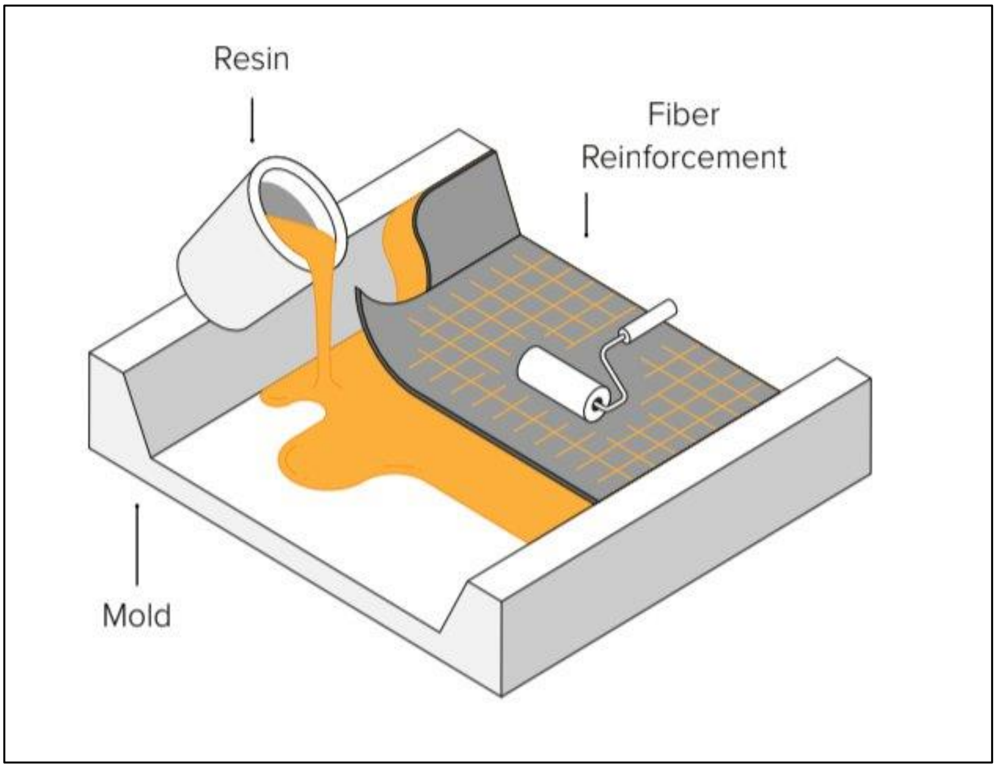

Fig.3.5 Hand layup technique.

Steps carried out in hand layup technique follows:

- A proper glass mould is taken.
- Wiped it with Acetone to remove impurities.
- Wax is coated on it.
- Peel ply of accurate size is fixed on it.
- Required amount of resin and fibre is taken.
- Added FLORA BL50 (RESIN) as a layer and added a layer of glass fibre above the mould.
- 7 such layers are added above the first layer and added adequate amount of the light sensitive resin and covered with peel ply.
- Adequate pressure is applied with the help of roller brush.
- Taken for curing.

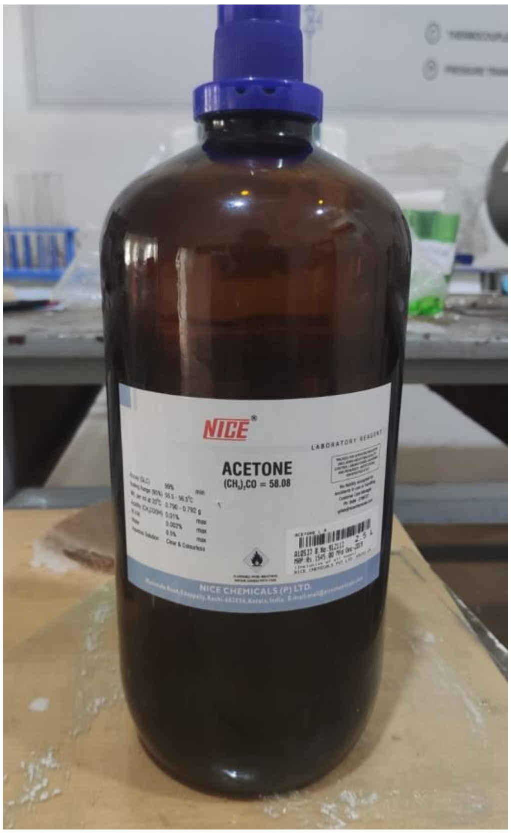

Fig.3.6 Acetone used for cleaning.

Acetone (CH_3COCH_3), known colloquially as 2-propanone or dimethyl ketone, is an organic solvent with enormous chemical and industrial significance. It is the most basic and prominent of the aliphatic (oil-derived) ketones. Pure acetone boils at 56.2 °C (133 °F), is transparent, moderately fragrant, combustible, and mobile. Acetone is a liquid solvent that can disintegrate and break down other materials.

Acetone is widely used in the following fields:

- Industrial
- Solvent
- Acetylene carrier
- Chemical intermediate
- Laboratory

- Chromatography
- Chemical research
- Cleaning
- Low-temperature bath
- Histology
- Lewis base properties
- Medical
- Drug solvent and excipient
- Skin defatting
- Anticonvulsant
- Domestic and other niche uses

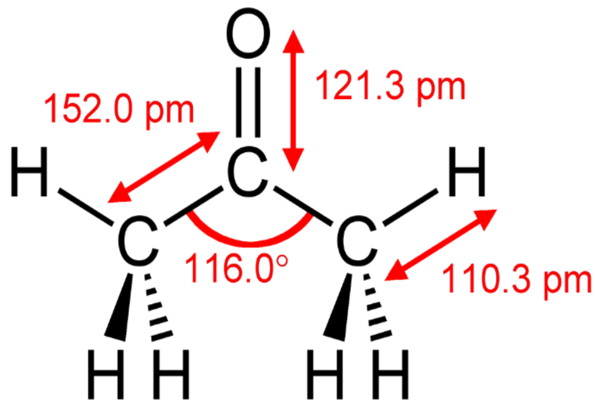

Fig.3.7 Full chemical formula of Acetone.

Low-grade acetone is also commonly used in academic laboratory settings as a glassware rinsing agent for removing residue and solids before a final wash.

Fig.3.8 peel ply.

Fig.3.9 Roller brush used for pressurizing.

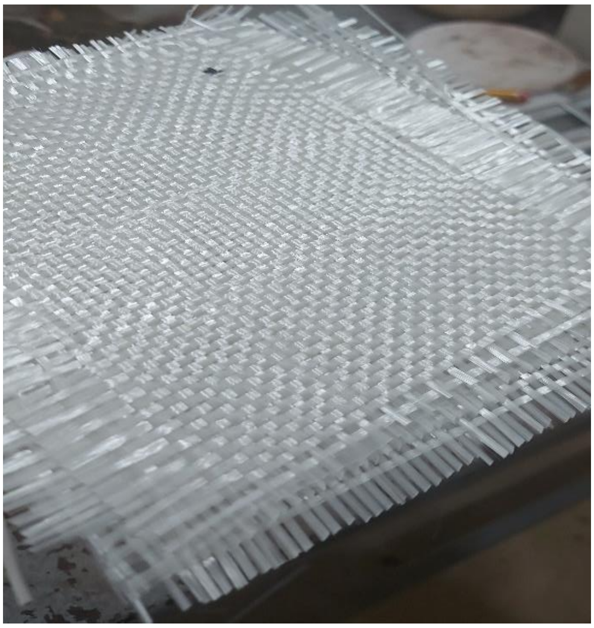

Fig.3.10 Glass fibre sheets.

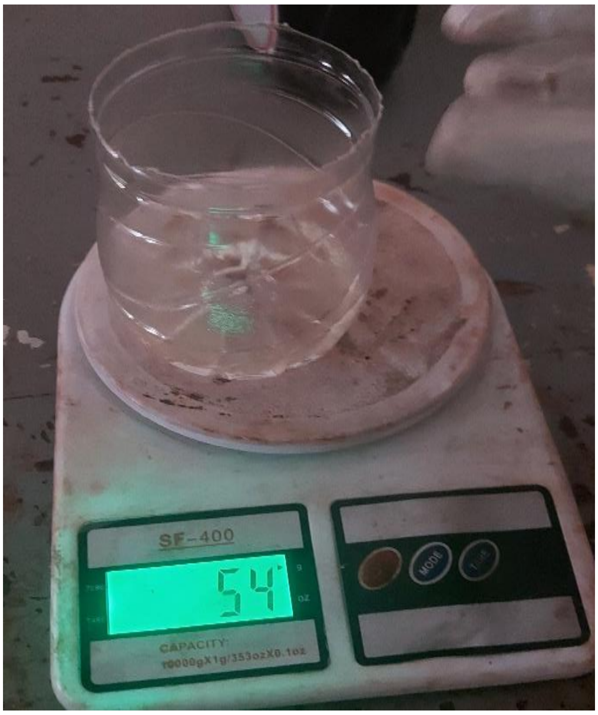

Fig.3.11 Photopolymer resin taken.

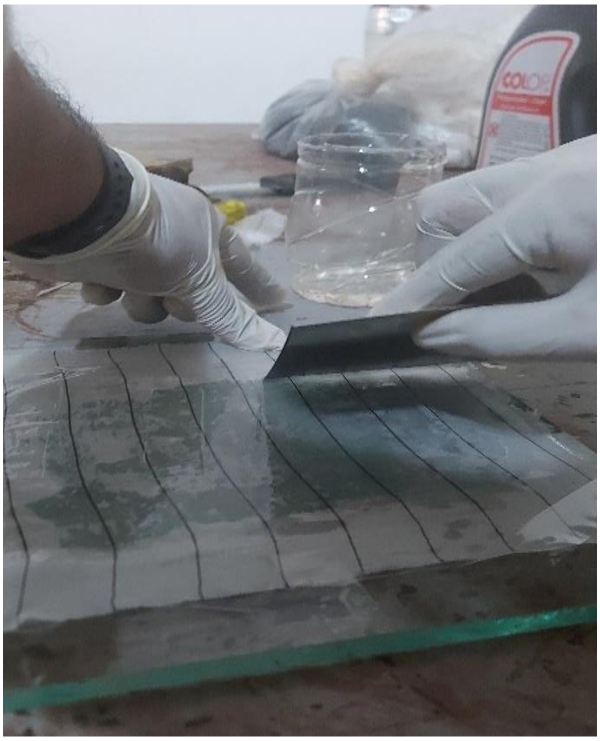

Fig.3.12 Photopolymer pasting.

Fig.3.13 Glass fibre placing.

Fig.3.14 Fabrication by Hand layup.

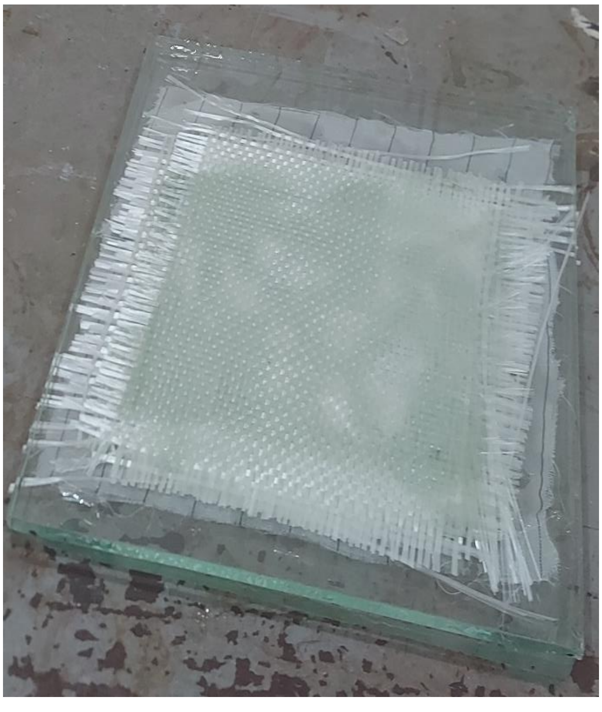

Fig.3.15 Fabricated sample.

3.3 PHASE OF CURING

Curing of GFRPP composite samples is done by two techniques. Few samples are cured with the aid of direct sunlight, while others are cured with the aid of specified UV lamp. The sample taken for direct sunlight curing is taken outside the laboratory room and placed where maximum sunlight receives. UV led lamp consist of power supply module and a closed cabin for placing the sample for curing. The samples are taken out after cycle time completes. The former composite sample is compared with the later composite sample to identify the variation in properties.

Table 3.3 Curing strategies followed.

Type of curing	Space of curing	Cure cycle
Direct sunlight	Open space with sunlight	72 hours
UV lamp	Closed cabin box	48 hours

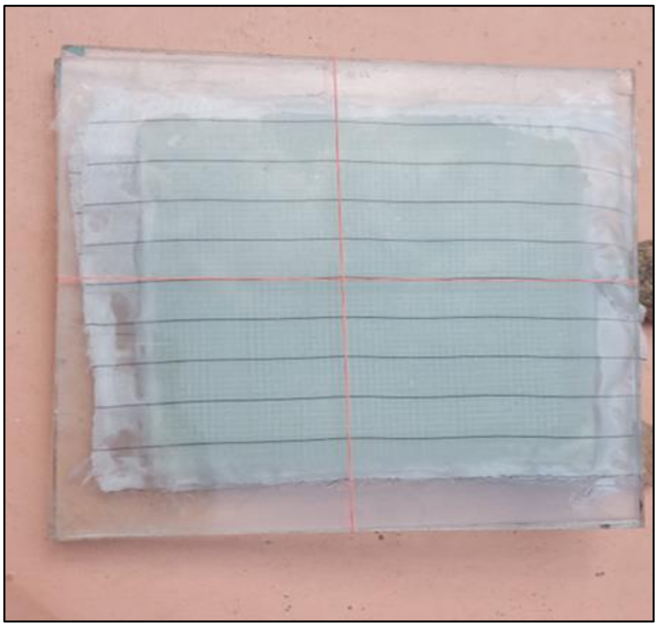

Fig.3.16 Composite curing in direct sunlight.

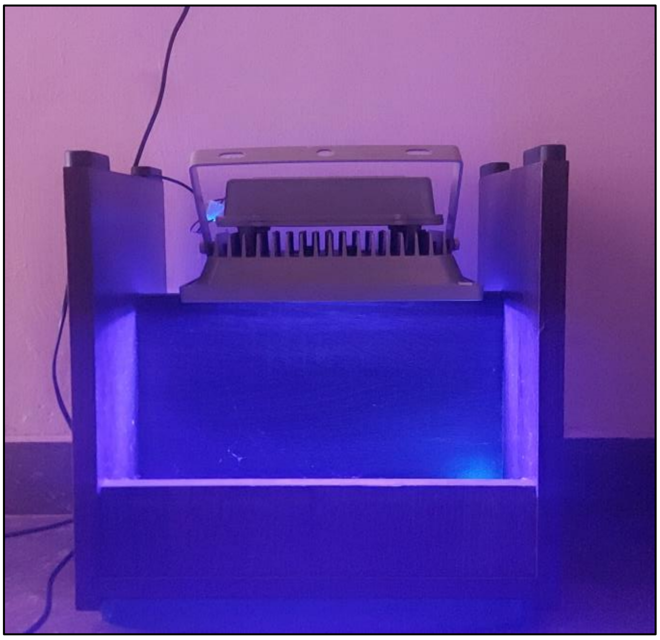

Fig.3.17 Composite curing with UV lamp setup.

3.3.1 Direct Sunlight Curing

The direct sunlight curing technique is based on UV radiation curing technique. Sunlight has radiations of infrared, visible and ultraviolet regions. Ultraviolet radiation is a kind of non-ionizing radiation that is send forth by the sun.

Fig.3.18 Sunlight cured sample.

UV rays in sunlight is subdivided into three waves depending on the energy levels. Those are UV A, UV B and UV C. UV A has sufficient energy to initiate polymerization. When UV rays strikes on the radiation sensitive polymers, hardening of resin occurs by the use of high energy electromagnetic radiation by light receptors. The GFRPP composite samples fabricated is taken for curing in an open space where maximum sonar energy received. The photopolymerization will initiates and terminates at fully cured condition with a cure cycle of 72 hours. After removing the cured sample from the mold, it is examined.

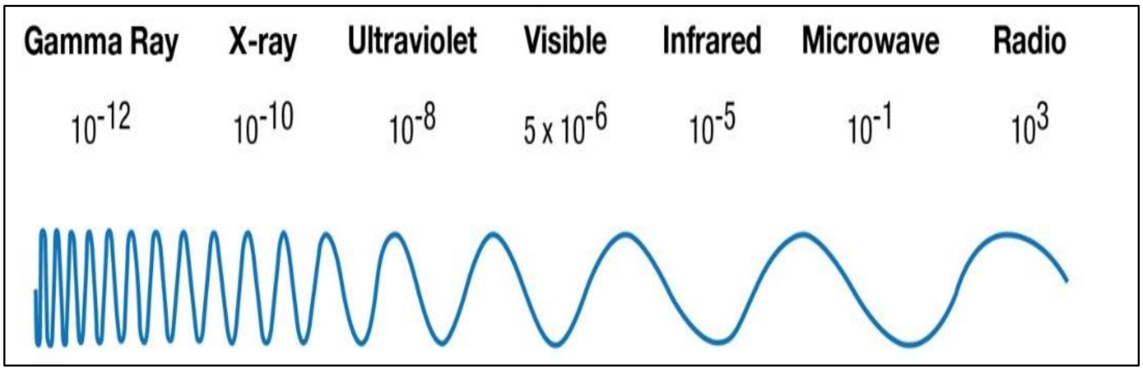

Fig.3.19 Electromagnetic wave spectrum

Table 3.4 Types of UV and their Ionizing capacity.

ELECTROMAGNETIC WAVES	**IONIZING CAPACITY**
1. UV A	HIGH
2. UV B	MODERATE
3. UV C	LOW

Fig.3.20 Atmosphere condition measured.

Table 3.5 Atmospheric data measured.

Atmospheric conditions	Values
Percentage of relative humidity	84.1 %RH
Temperature	26.6 °C

3.3.2 Ultraviolet Lamp Curing

UV-curing technique is more reliable, efficient, power-saving, environmentally sustainable and user friendly. UV-curing is technology widely used in curing of coating and thin films. Ultraviolet radiation can also be created by artificial sources such as lamps, tubes etc. UV A type LED lamp is wired to complete its circuit. After the completion of the circuit, the lamp is fixed in the inside top portion of a closed box. Hence the box system for UV curing is fabricated.

Table 3.6 UV wavelengths and penetrating capability.

UV type	Wavelength in nm	Penetrating capability
UV A	315-400	High
UV B	280-315	Moderate
UV C	100-280	Low

Few fabricated GFRPP composite samples are taken and placed in the deck of the UV curing box. Circuit turned on will initiate the curing mechanism. After cycle time is completed the GFRPP composite samples placed inside the UV box is taken out and examined. Since UV box contains 100% of UV, the cure cycle is found to be only 48 hours. These samples are similar in physical appearance to that of direct sunlight cured samples.

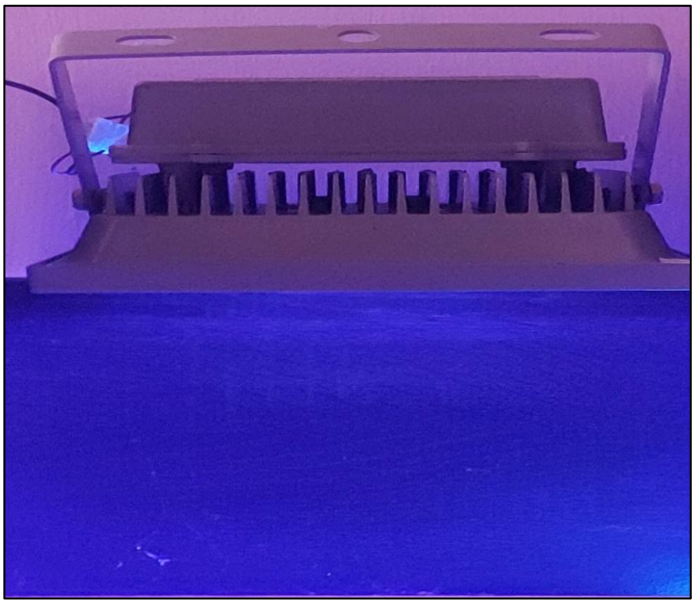

Fig.3.21 Artificial UV setup.

Fig.3.22 Artificial UV cured sample.

3.3.3 Curing Cycle

Curing cycle is depicted as the total time taken for complete the cycle of curing from initiation of photopolymerization to termination of photopolymerization. Curing cycle is considered as an important variable in determining the fabricated sample of GFRPP composite properties. Cure cycle varies relating to GFRPP composite sample thickness, exposure to waves, type of fabrication process followed.

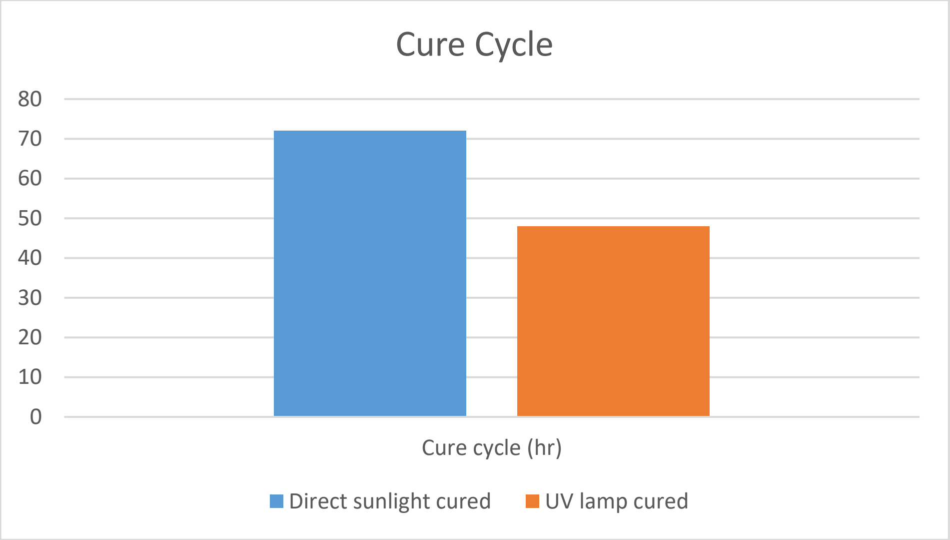

Fig.3.23 Cure cycle in hours.

The direct sunlight cured light sensitive photopolymer composites shown a cure cycle of 72 hours in direct sunlight exposure. It is because of the fact that the sunlight contains only 10 percentage of UV on scale of 100 percentage. Further, it depends on the atmospheric condition as well as the place where it carried out for curing.

While the UV light source cured light sensitive photopolymer composite shown only 48 hours of curing only. It is because of the fact that the percentage of UV light on scale of 100 percentage is almost 100 inside the closed box illuminated with UV A type LED lamp.

From the curing cycle it is noted that the UV lamp curing is much less time consuming to be fabricated while comparing with direct sunlight curing. But in the case of energy efficiency, sunlight curing is the better way.

CHAPTER 4

MATERIAL TESTING

Materials testing can reveal a great deal of information about the investigated samples, prototypes, or product samples for a variety of reasons. Engineering field can benefit much from the data gathered during testing and the test findings themselves. Glass fibre reinforced photopolymer composite material cured with the aid of direct sunlight must prove its applicability while comparing with UV lamp cured specimen. In order to prove its applicability and variation with conventionally cured sample, the material is taken for different mechanical testing's. Two samples selected from each of direct sunlight cured and artificial UV cured respectively for testing.

Fig.4.1 Sunlight cured specimen for testing.

Fig.4.2 UV A type lamp cured specimen for testing.

4.1 BRINELL HARDNESS TEST

Hardness is accounted as a major characteristic of a structural material. It is delineated as the resistance to applied indentation, and it is calculated by measuring the permanently formed depth due to indentation. By measuring the size of an indentation created by an indenter, Brinell Hardness Testing technique determines the hardness of a metal. A softer material is indicated by bigger surface indentations made by the Brinell Hardness Testing Machine at a certain ball diameter and test force.

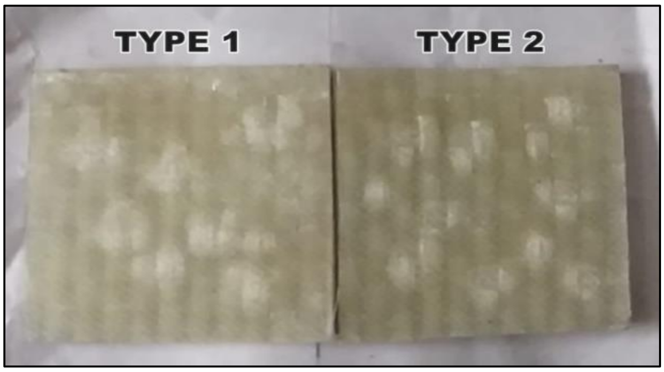

Fig.4.3 Hardness tested samples of each type.

Table 4.1 Hardness values.

Sample type	Total readings.	Values (BHN)	Mean Value (BHN)
Direct sunlight cured	5	40,41,39,41,44	41
Artificial UV cured	5	37,41,38,39,40	39

Two samples taken such as Type 1 and Type 2 is selected from samples of direct sunlight cured and artificial UV cured respectively. These samples tested for hardness values at Strength of Materials Lab, TKMCE, Kollam and Type 1 shown a mean value of 41 BHN while Type 2 shown a value of 39 BHN.

4.2 ROUGHNESS TEST

Roughness of surface is considered as the major component of surface texture. It is delineated as imperfections and deviation of surface from its ideal position. To quickly and precisely determine a material's surface texture or surface roughness, a roughness tester is utilised. A roughness tester displays the mean roughness value (Ra) and the measured roughness depth (Rz) in microns.

Results of roughness test on the fabricated GFRPP novel composite material addresses the variables such as controllability and quality of fabricated samples. Roughness test on GFRPP specimen shows the roughness depth (Rz) for Type 1 and Type 2 are 4.731 µm, 4.244 µm respectively as well as the mean roughness value (Ra) for Type 1 and Type 2 are 2.172 µm, 1.997 µm respectively for a span of 4mm length. The root mean square roughness value (Rq) for Type 1 and Type 2 are 2.374 µm, 2.519 µm respectively for a span of 4mm length Units are in µm.

These samples tested for roughness values at Mechanical engineering lab, TKMCE, Kollam. No much variations in both specimens observed. Hence the surface texture characteristics of both specimens fabricated by hand layup technique and cured in direct sunlight as well as UV LED lamp box respectively shown similar.

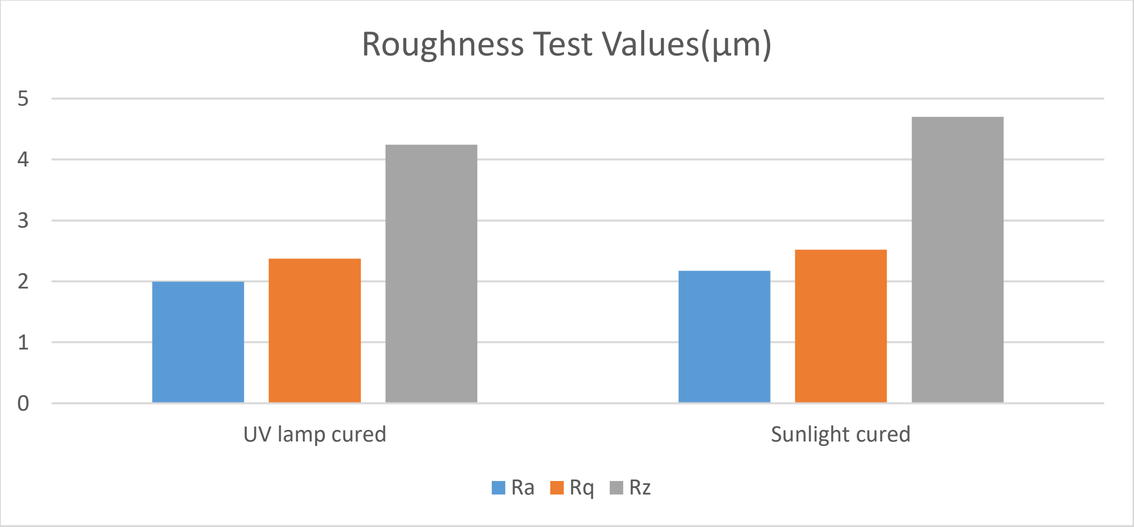

Fig.4.4 Roughness chart

Fig.4.5 Roughness tested sample of direct sunlight cured type.

Fig.4.6 Roughness tested sample of UV lamp cured type.

Table 4.2 Roughness values.

Sample type	Ra (µm)	Rq (µm)	Rz (µm)
Artificial UV cured	1.997	2.374	4.244
Direct sunlight cured	2.172	2.519	4.731

4.3 TENSILE STRENGHT TEST

The utmost load that GFRPP material can bear without being fracture when it is stretched is experimentally identified by tensile strength (σ) test. Two specimens such as Type 1 and Type 2 is selected from samples of direct sunlight cured and artificial UV cured respectively. These specimens tested for tensile strength values at CIPE Technology, Cochin and Type 1 shown a value of 59.37Mpa while Type 2 shown a value of 73.12Mpa.

Table 4.3 Tensile strength values

Sample type	Test Method	Unit- Mpa
Direct sunlight cured	ASTM D 638	59.37
Artificial UV cured	ASTM D 638	73.12

Fig.4.7 Specimens of each type submitted for tensile strength test.

4.4 CALCULATION OF DENSITY

The density of GFRPP material is its mass per unit volume. The symbol most often used for the intensive property density is 'ρ' although the Latin letter 'D' can also be used in certain cases. Two specimens such as Type 1 and Type 2 is selected from samples of direct sunlight cured and artificial UV cured respectively.

These specimens are identical in dimension. The dimension of both specimens is 10cm*10cm*0.4cm. Both the specimens are weighted in precision balance and found 110.640 grams and 120.848 grams. While calculating and converting the value of centimetre to metre we get the values of volume as $40m^3$ and converting gram to kilogram weighed in precision balance for artificial UV lamp cured and direct sunlight cured specimens as .12 kg and .11 kg respectively.

Table 4.4 Density calculations

Sample type	Mass (gram)	Volume (cm^3)	Volume (m3)	Density (g/cm3)	Density (Kg/m^3)
Sunlight cured	110	10*10*0.4	40	2.65	2650
UV lamp cured	120	10*10*0.4	40	2.7	2700

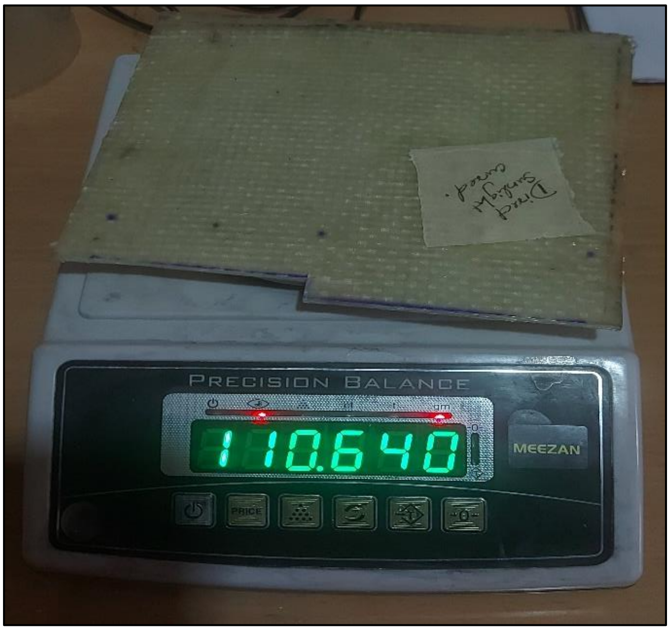

Fig.4.8 Sunlight cured specimen weighing in precision balance.

Fig.4.9 Artificial UV cured specimen weighing in precision balance.

CHAPTER 5

COMPARATIVE ANALYSIS

Both of the two specimens such as direct sunlight cured Type 1 and artificial ultraviolet lamp cured Type 2 is selected from samples and tested Brinell hardness test, Roughness test and Tensile strength test. The results of those test are noted and compared in the phase of analysis. Only acceptable variations are found between both direct Sunlight cured Type 1 specimen and artificial ultraviolet cured Type 2.

Hardness value of direct sunlight cured Type 1 specimen is found greater than that of artificial UV cured Type 2. Type 1 shown a value of 41 BHN while Type 2 shown a value of 39 BHN for hardness test. In the case of Tensile strength test direct Sunlight cured Type 1 specimen shown a value of 59.37Mpa while artificial ultraviolet light cured Type 2 shown a value of 73.12Mpa of tensile strength.

Results of roughness test on the fabricated GFRPP novel composite material addresses the variables such as controllability and quality of fabricated samples. Roughness test on GFRPP specimen shows the roughness depth (Rz) for Type 1 and Type 2 are 4.731 µm, 4.244 µm respectively as well as the mean roughness value (Ra) for Type 1 and Type 2 are 2.172 µm, 1.997 µm respectively for a span of 4mm length. The root mean square roughness value (Rq) for Type 1 and Type 2 are 2.374 µm, 2.519 µm respectively for a span of 4mm length Units are in µm.

The variations in the values yield from results of test are minimum and comparable. Hence Sunlight curing of composites helps to explore its usefulness as a sustainable, renewable as well as cost-effective production technique without unacceptable sacrifices of structural properties.

Fig.5.1 Type 1 sunlight cured specimen.

Fig.5.2 Type 2 artificial UV cured specimen.

CHAPTER 6

APPLICATIONS

Material is the most significant aspect that goes into making and creating things on any scale, from the microscopic to the planetary. Ceramics, metals, and polymers are the three basic categories of material that have historically existed. These three categories of materials are used in the construction of the majority of common objects. Composites are a brand-new kind of material that has been identified in the past century. This content is a combination of multiple materials that come together to create something better.

The applications of Advanced Glass Fibre Reinforced Polymers (GFRP) elements have spread steadily during the last few decades, as they became extremely favoured in wide variety of distinct areas of the automotive, aerospace, marine, structural and civil construction industries. Both of the two specimens such as direct sunlight cured Type 1 and artificial ultraviolet lamp cured Type 2 is selected from samples and tested Brinell hardness test, Roughness test and Tensile strength test.

Even though only acceptable variations are found between both types, those values are slightly less than that of ordinary GFRP composites. Hence the newly fabricated GFRPP composites can be used as structural elements in various fields. The advantages such as low weight to strength ratio, low density, low porosity, corrosion resistance capability, ease and cost-effective manufacturing etc make its applications broader. The important variable that makes GFRPP composite special is that one can tailor its properties depending on the light sensitive resin used in fabrication.

A significant market for composite science is found in sports and leisure. Boats are frequently composed of reinforced polymers, which makes them easy to float and lightweight enough to go through water at great speeds. Composites can be used in clubs of golf, bicycles, and firearms to enhance performance. It's possible that the biggest incentive for composite research comes from aerospace applications. When it comes to making things fly, weight and strength are a major concern, and composites succeed in both fields.

In the past several years, there has been a substantial advancement in the understanding of the structural response of GFRP members, and this information has been incorporated into design. Those includes structures of ladders, platforms, handrail systems, tank. The GFRPP composites can also use as bodies of automotives and equipment's, cabin walls, safety boxes, temporary roof top of stadiums like ETAR Vilamoura in Portugal etc.

In the field of electronics GFRPP can be widely used for circuit board manufacture, TVs, radios, personal computers, cell phones, electrical motor covers etc. In the area of home and furniture GFRPP can be used roof sheets, bathtub furniture, windows, sun shade, show racks, book racks, tea tables, spa tubs etc. While in automobiles GFRPP can be used extensively used for automobile parts like body panels, seat cover plates, door panels, bumpers etc.

Furthermore, UV curing can be used for localized fabrication of composite panels, automobile bodies and marine vehicles. While the direct sunlight curing technique can be applicable in temporary roof by laying the fibres and uncured resin. The curing takes place in the service time itself.

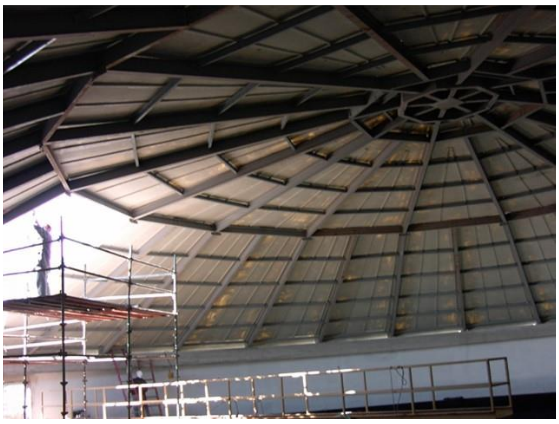

Fig.6.1 GFRP as roof top in ETAR Vilamoura in Portugal.

Fig.6.2 Localized fabrication with GFRP in boats.

Fig.6.3 GFRP composites as cabin panels.

CHAPTER 7

COST ANALYSIS AND GANTT CHART

7.1 COST ANALYSIS

Table 7.1 Cost analysis.

Type of expenditure	Specification/Items	Estimate amount (Rs)	Actual amount (Rs)
Flora BL50C Resin	5 litres	2500	2407
Glass fibre sheets	5 meters	1000	1400
Raw Materials	Scissors, brush, etc	1000	650
Acetone	1 litre	1000	791
Peel ply	1 meter	300	300
Wax	200 grams	100	100
Testing	Hardness, Tensile	5000	4000
Miscellaneous			700
Total		10900	9648

The table 7.1 shows the estimated budget for the experimental investigation and the overall expenses of the study. The overall expense of the work does not exceed the estimated budget even though some miscellaneous expense occurs and was budget friendly.

7.2 GANTT CHART

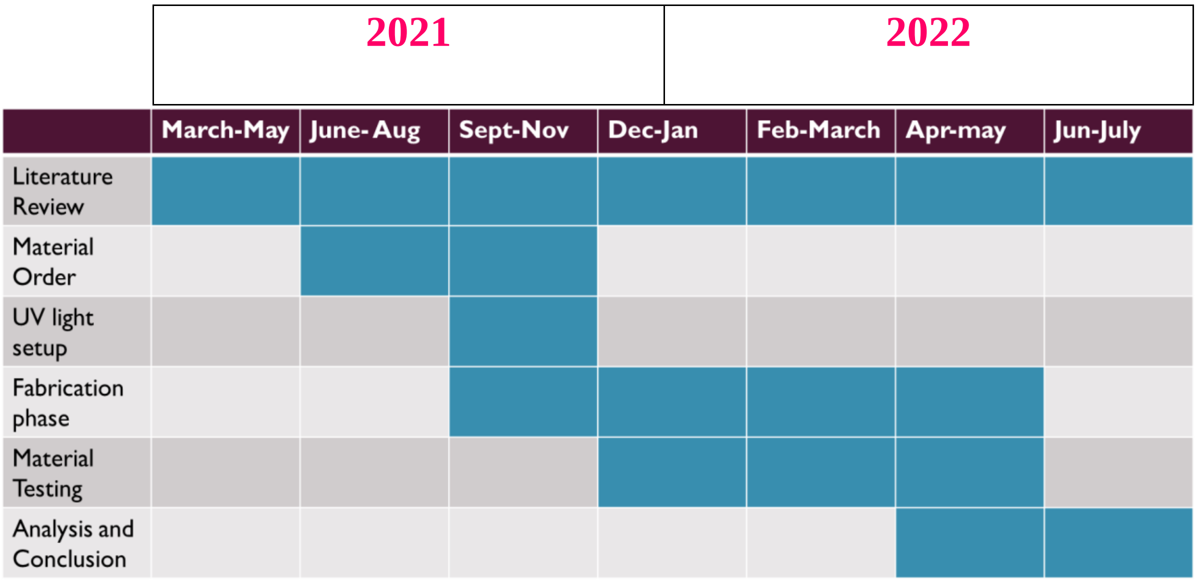

Fig.7.1 Gantt chart

Fig7.1 shows the Gantt chart form, which represents the total timeline indicating the time of beginning and ending of each stage in the experimental investigation study. It takes around 16 months to complete the entire investigation.

CHAPTER 8

CONCLUSION

The production of advanced photopolymer composites is of elevated academic and industrial importance when considering low cost, highly effective curing techniques. The following factors, such as material accessibility, universality, and potential, applicability in curing speed, handling complexity, controllability, and penetration potential on matrix, carbon fiber, and natural fiber, need to be fully considered carefully when choosing a suitable curing mechanism. Owing to the peculiar energy absorption approach used in the radiation curing mechanism, radiation offers distinct technological advantages over thermal curing, such as quick curing times, increased resin stability, and more. In contrast to thermal curing procedures, it also offers a great deal of technical flexibility and some process latitude to build huge, complicated structures. However, radiation curing requires specifically prepared radiation-sensitive material for application. Considering the established thermal curing material system and curing methods, UV curing mechanisms is by far the most prevalent curing method for composites. We can use sunlight for UV extraction, which results in a minimal energy strategy. A sample made using Flora photopolymer and reinforced with fiberglass is deemed to be of excessive quality. More samples made from a range of fibers will be produced. To demonstrate the applicability of composites, testing in a structural laboratory is required. Thus, it is evident that the UV-cured photopolymer composite samples have more potential for use in manufacturing and material science.

The following conclusions were drawn from the experimental results:

- While comparing results of direct sunlight cured photopolymer composites with artificial UV cured photopolymer composites, the variation in the values is minimum.

- Sunlight cured composites explored its usefulness as a sustainable, renewable as well as cost-effective production technique without unacceptable sacrifices of mechanical properties.
- Hence direct sunlight curing technique can be implemented as an alternative for artificial UV curing techniques.
- Sunlight curing applied in applications like laying roof without curing the resin. It will be cured in the service itself.
- UV curing can be accounted as a good technique for localized fabrication of ships, automobile, etc.

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