# ROLE OF THE NANO-PARTICLES INCLUSION IN THE STRUCTURAL INTEGRITY OF HONEYCOMB SANDWICH STRUCTURES

A Final Year Project Report

Presented to

**SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING**

Department of Mechanical Engineering

NUST

ISLAMABAD, PAKISTAN

In Partial Fulfillment
of the Requirements for the Degree of
Bachelors of Mechanical Engineering

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May 2022

# ABSTRACT

Engineering applications continue to draw interest in laminated structures made of sophisticated filamentary composite materials. Their key characteristics are their high strength-to-weight ratio and the ability to custom-make diverse components with strength much exceeding the parent constituent materials. And then if we combine these laminate layers with a honeycomb structure we can a material which shows a tremendous strength. We want to improve the strength of different interfaces in the composite. Interfaces are basically the main points where any structure can break. These are the weakest points in any structure. There are several interfaces in our composite. There are 5 interfaces between layers of Glass fiber face sheets. Besides this, 2 more interfaces are present between face sheets and the honeycomb (above side and below side face sheets). We want to strengthen these interfaces which will increase the overall strength of the structure. This is what will be the main focus for our project finding. We will make different batches of laminates using fiber glass and different percentages of Nano-particles with a honey comb structure and then test its strength.

# ACKNOWLEDGMENTS

The honeycomb sandwich panels are prepared in the National Centre for Physics (NCP), Islamabad, Pakistan using the facilities available there. The raw material for preparation of samples was provided by NCP.

We would like to express our gratitude to our mentors who supported, motivated & guided us at every step.

Our profound thanks and appreciation goes to Dr. Adnan Munir who was extremely patient, kind and very helpful during this whole project. Besides this, he also guided us in completing and refining our thesis under his guidance.

We wish to express our deepest thanks and heartfelt appreciation to Dr. Aqeel Ahsan Khurram for his friendly and co-operative attitude. He was very helping and thoroughly guided us at each and every step throughout the whole process. We would also like to thank the staff of NCP for their support and necessary help during the laboratory work.

# ORIGINALITY REPORT

All the work shown in this report is our own work. We have prepared our samples and have tested those samples on 3-point flexural bending and flatwise tensile loading. We have added references of the sources we have used for the help.

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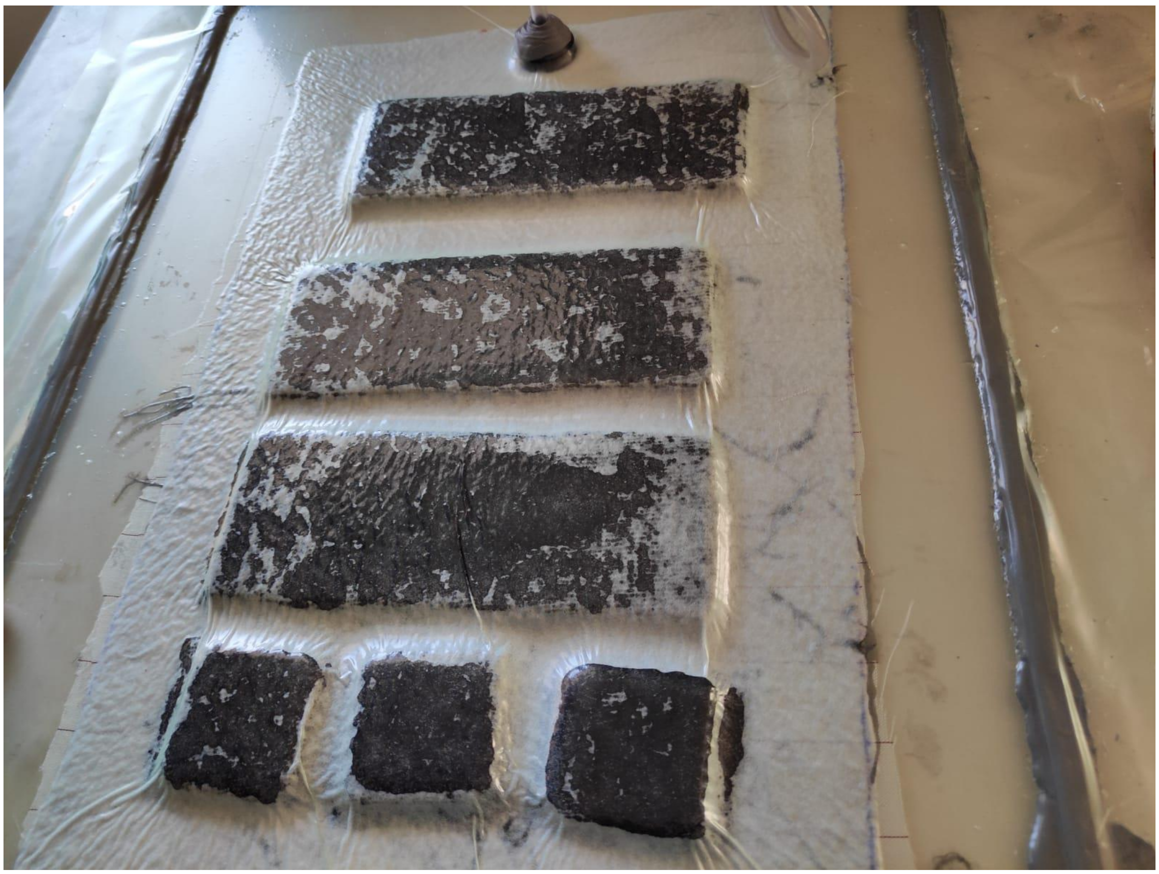

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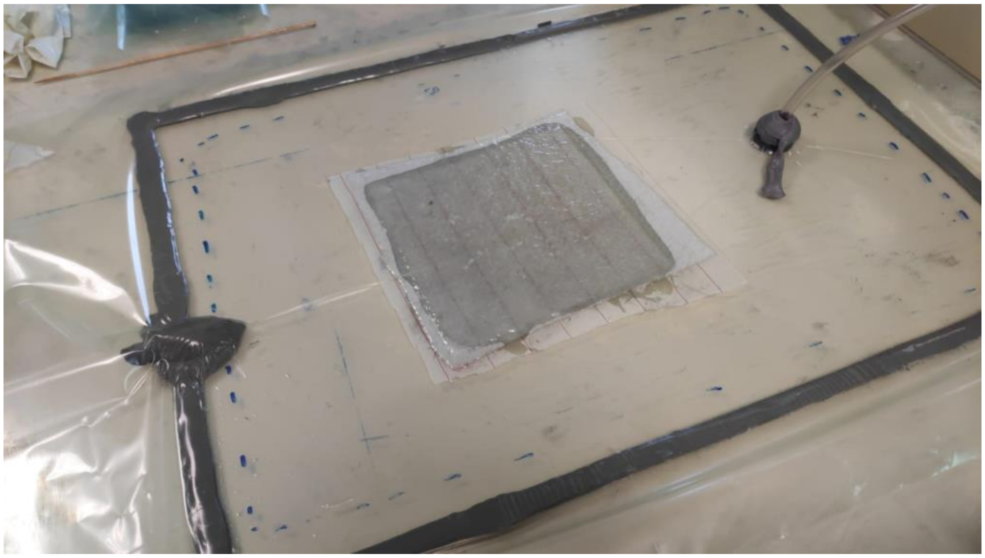

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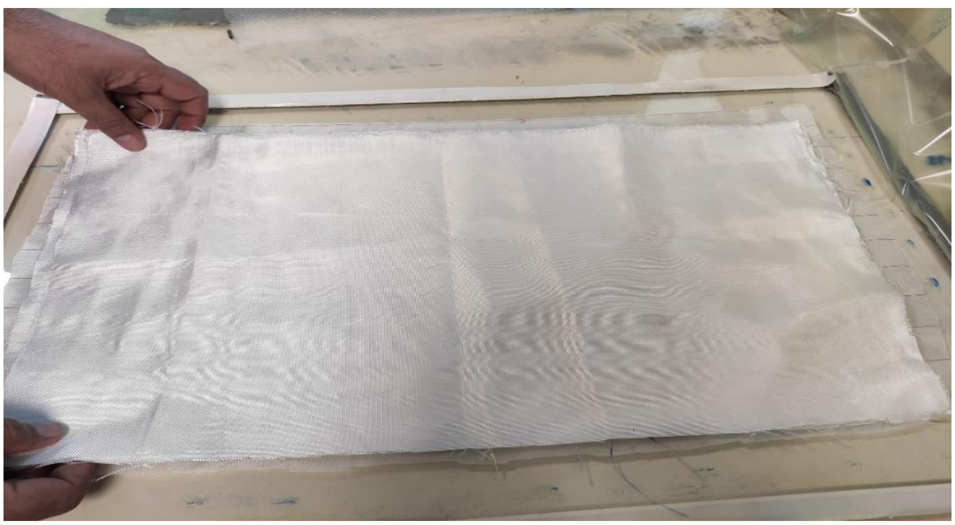

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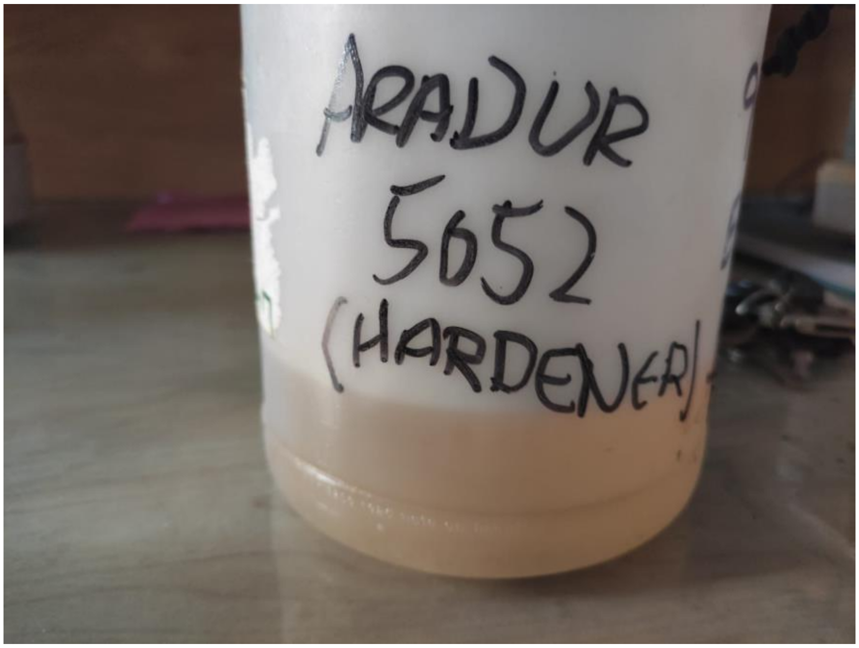


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# ABBREVIATIONS

| | |
|---|---|
| NCP | National Center for Physics |
| GNPs | Graphene Nano-Particles |
| CNTs | Carbon Nano-Particles |
| UTM | Universal Testing Machine |
| HC | Honeycomb |
| PVA | Poly Vinyl Acid |
| GFRP | Glass Fiber Reinforced Polymer |

# CHAPTER 1: INTRODUCTION

Composite materials are hybrid materials having exceptional and combined properties of component materials with a continuous phase (matrix) and a discontinuous phase (reinforcements). Epoxy is the matrix and Nano-particles are reinforcements in our case. Epoxy is a resin which is available in liquid form. When we add a certain amount of hardener to epoxy, it transforms to solid phase and binds the reinforcement material together to form a hybrid composite. The use of Nano-particles (Carbon Nano Tubes and Graphene Nano Particles) is very effective is this case. Nano-particles offer high thermal conductivity, high electrical conductivity, greater aspect ratio, impermeability and high tensile strength. They are very small in size and offer a greater surface area. The reinforcement is added to epoxy and then stirred using magnet under temperature and cured if needed. The 6-layered Glass fiber face sheets are used which provide high tensile strength and honeycomb as core which offers effective resistance to bending. These are combined using epoxy. Strength of glass fiber and Honeycomb combine to give a strong sandwich structure. Strengths are tested under 3-point flexural bending & Flatwise tensile testing.

## 1.1 Overview:

The thesis is divided into 5 chapters. The first chapter consists of a brief introduction, which includes objective, motivation & future prospects/applications.

Second chapters include Literature review related to the experimental work performed.

Third Chapter describes the Methodology and all the steps followed in the project

Fourth chapter is about Results and Discussion. Results are obtained by the tests performed on the samples to get the maximum strength.

Fifth chapter discusses the Conclusion obtained from the results and experimental work. We will discuss some recommendations also.

## 1.2 Objectives:

Following are the objectives for our project:

- Prepare a light weight material which will save fuel consumption
- Include of Nano-particles in the GFRP composites to improve strength of the structure and enhance the strength of interfaces in the sandwich panel
- Prepare a cost effective yet a very strong material to be used in various practical applications

## 1.3 Motivation:

The strength and efficiency of the polymer can be greatly improved by adding the Nano-particles (reinforcements). Nano-composites have excellent properties due to large interfacial area between polymer matrix & Nano-particles. Nano-particles possesses excellent thermal, electrical and mechanical properties. Therefore, we want to develop a composite material that is light in weight, cheap, easily available and can replace the expensive & heavy metals by possessing the comparative properties and strength.

## 1.4 Future prospects & Applications:

These composite structures are ultra-lightweight. Honeycomb cells are hollow from inside which makes it light weight (low density) but possesses high bending resistance. Due to excellent mechanical, electrical and thermal properties of Nano-particles, tensile strength of glass fiber and bending strength of honeycomb core combined, this composite structure finds its emerging applications in aerospace, automobile, and marine applications. They are also used in automotive parts, boat hulls, sporting goods, water filters, thin-film electronics, coatings, actuators and electromagnetic shields. Due to high strength-to-weight ratio, these composite materials can be used to make airplane wings, turbine blades etc. Recently, composite materials have been increasingly considered in civil engineering structures. These are economically feasible as well and doesn't cost too much but provides many benefits.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Background:

At the nanoscale scale, material physics is different. The nanometer scale ranges from one to hundred nanometers. One billionth of a metre equals a nanometer. Nanoscience is the study of atoms, molecules, and things with dimensions in the nanometer range. Nanoscience measures less than 100 nanometers in length. Materials have unique features at the nanoscale scale. Nanoscale properties differ dramatically from micro and macroscale properties. Nanomaterials have very different physical, chemical, and biological properties than solid materials. Some features of materials, such as quantum mechanical and thermodynamical properties, are not visible at the macro level but become essential at the nano level. It's a little field with a lot of promise.

Nanotechnology refers to the synthesis and manufacturing of materials and devices with dimensions smaller than 100 nanometers. Massive surface area, homogeneous size distribution, shape, crystallinity, and agglomeration are some of the issues encountered during the creation and processing of nanomaterials and nanostructures. Nanomaterials have a high surface energy due to their great surface to volume ratio, which causes agglomeration.

Nanomaterials have been divided into three main classes:

1. Zero dimension (0D)
2. One dimension (1D)
3. Two dimension (2D)

This classification is done based on their dimensions, like 0D materials have all the dimension in nanometric scale. Nanoparticles are the most common 0D nanomaterials. 1D materials have 1 dimensions outside nanometric scale like Nanotubes, nanorods, and nanowires and 2D materials include 2 dimensions outside nanometric scale like Graphene, nanofilms, nanolayers, and nano-coatings.

## 2.2 Glass Fibers:

Glass fibre reinforced polymer composites have been manufactured using a variety of techniques and are widely employed in a variety of applications. Glass fibres produced from heat softened glass were first used by ancient Egyptians to make vessels. Glass fibres for high-temperature electrical applications were first made in the 1930s, according to Continues. It is now employed in electronics, aircraft, and vehicle applications, among other things. Glass fibres have great qualities such as strong strength, flexibility, stiffness, and chemical resistance. It might take the shape of rovings, chopped strand, yarns, textiles, or mats. Glass fibres come in a variety of shapes and sizes, and they're employed in polymer composites for a variety of purposes. Various glass fibre reinforced polymer composites' mechanical, tribological, thermal, water absorption, and vibrational characteristics were described.

In areas such as transportation and infrastructure, the usage of glass fibre composites provides several potential benefits in terms of extended lifespan, weight reduction, and cost. We need to incorporate polymer composites deeper into our economic infrastructure by being able to forecast their performance precisely and reliably throughout their lifetime in order for them to be utilised to their full potential in terms of structural strength. Understanding the causes behind the loss of mechanical qualities in glass fibre composites is difficult, however, because each ingredient has the potential to be the structure's weak point. Furthermore, synergy between these degradation mechanisms has the ability to degrade composite qualities at a quicker pace than the rates of deterioration for the individual components predict.

## 2.3 Nano-Particles:

Nano particles are basically very small structures with the dimensions less than 100nm. A broad class of materials, with microstructures modulated in zero to three dimensions on length scales less than 100 nm. Atoms are arranged in Nano-sized clusters, which become the building blocks of the material.

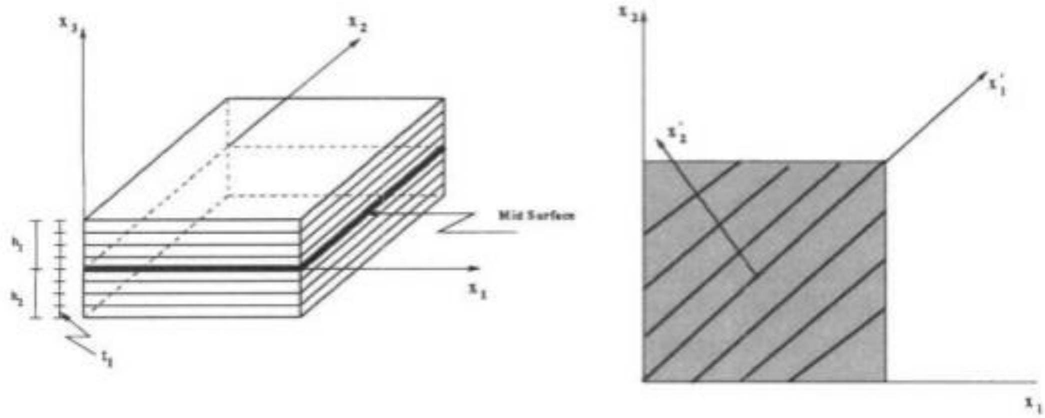
A nanocomposite is a matrix to which nanoparticles have been added to improve a particular property of the material.

## 2.4 Classical Lamination Theory:

CLT (classical lamination theory) is a widely used prediction technique that was developed in the 1960s and allows for the analysis of complicated coupling effects in composite laminates. It can forecast stresses, displacements, and curvatures in a laminate as it is mechanically and thermally loaded. The technique is similar to isotropic plate theory, with the main contrast being the stress-strain relationships in the lamina.

### 2.4.1 Laminate Analysis:

The classical lamination theory is used to perform laminate analysis. A lamina layup of 2n layers is symmetrically placed with their distinct in plane orientations with regard to the mid plane in this work. (x1, x2, x3) are the global coordinates for the plate, while (x'1, x'2, x'2) are the local coordinates for the lamina. Figure 1 depicts them.




(a) Laminated Composite Plate

(b) Lamina Local Coordinate System

Figure 1

The following statement can be used to link the laminate in plane forces and out of plane moments to the deformation and curvature of the laminate.

$$\begin{bmatrix} \boldsymbol{N} \\ \boldsymbol{M} \end{bmatrix} = \begin{bmatrix} \boldsymbol{A} & \boldsymbol{B} \\ \boldsymbol{B} & \boldsymbol{D} \end{bmatrix}^{-1} \begin{bmatrix} \in \\ \kappa \end{bmatrix}$$

where

$$\boldsymbol{A} = \int_{-h_2}^{h_1} \boldsymbol{D}_k^{-1} dz, \boldsymbol{B} = \int_{-h_2}^{h_1} z\boldsymbol{D}_k^{-1} dz, \boldsymbol{D} = \int_{-h_2}^{h_1} z^2 \boldsymbol{D}_k^{-1} dz$$

where D is the kth ply's total stiffness matrix. D should be substituted by the elastic stiffness tensor, E, in the case of pure elastic behavior.

Although the classical lamination theory is the simplest and fastest to implement and solve numerically, it may result in erroneous predictions of the composite laminates' overall response. Because the local deformation could not be linked to the material's overall response. The functionally graded notion, which allows one to directly relate microstructural variation in local materials on the overall response of the laminated material, can be used to resolve this issue. However, in the current formulation, the damage criterion must include gradient elements that can be attributed to the nonlocal damage method.

## Limitations:

- Properties of material are highly anisotropic due to the orientation of fibers
- Strength perpendicular to the direction of alignment is considerably less (the fibers do not contribute)

Some of the challenges for the utilization of CNT in aerospace applications comprise of uniform CNT dispersion in composite structure, large-scale production method, adhesion and alignment issues in resistant polymers, and complete understanding of toxicity level. In terms of visual and thermal signature, lightweight, increased speed, and maneuverability, next-generation aircraft, rotorcraft, unmanned aerial vehicles, and missiles have severe concerns. These requirements, however, stimulate a need for advanced materials and systems. To meet these demands, CNT is an ideal candidate as it can be integrating in different technologies.

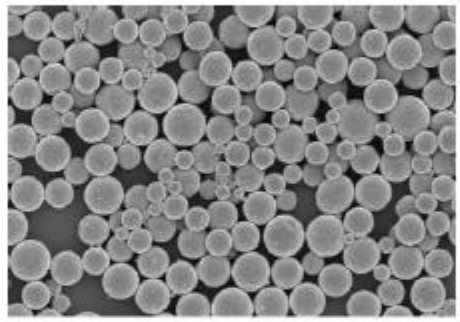
To date one of the few disadvantages associated with nanoparticle incorporation has concerned toughness and impact performance. Nano clay modification of polymers such as polyamides, could reduce impact performance.

## Types of Nano-composites:

–Nanoparticles (Three nano-scale dimensions)

–Nanofibers (Two nano-scale dimensions)

–Nanoclays (One nano-scale dimension)



Nanoparticles

**Why Nano-particles, not Fibers?**

The particle-filled composites have isotropic thermophysical features,

while fiber-filled composites have anisotropic thermophysical features.

**Why nanocomposites?**

Nano-composites are very small structures but possess a very good strength in them. They make the structure strong in which they get added and due to smaller size and weight, they do not add extra weight or space. A very little quantity of the Nano-particles is enough to make the structure way too strong. Nano-composites are preferred due to:

- Small filler size and small distance between fillers
- High surface to volume ratio

## Mechanical Properties:

Nano-composites possess extra ordinary mechanical properties and are a very important part of every structure demanding strength without compromising on weight and volume. Some properties of Nano-particles are:

- Increased ductility with no decrease of strength,

- Scratching resistance

- Provide a better penetration of the particles inside the body.

Future aerospace systems and recent progressive systems pursue to further improve both multifunctional and mechanical features of composite by the integration of nanoparticles.

## Carbon Nano Tubes (CNTs)

The excellent electrical, mechanical, and thermal characteristics of CNT render them ultimate applicant as Nano filler in lightweight polymer composite. Nanotube-strengthened polymer composites have become interesting structural materials not only in the weight-sensitive aerospace industry but also in the armor, marine, civil engineering structures, automobile, railway, and sporting goods. All these industries demand high specific stiffness and specific strength. Being advanced lightweight composites, they have numerous applications including sporting goods, aerospace structures, high-potential automobiles, aerospace and boats.

## Matrix-Filler Interactions

The reinforcing effect, which is dependent on the surface chemistry, size, and shape of the filler material, is the key to nanocomposite. Within a nanocomposite, there are three types of interactions.

These are:

- Interactions between fillers and fillers
- Interactions between matrices
- Interactions between the matrix and the filler

Filler-filler interactions cause agglomeration in filling materials, resulting in poor Nano filler dispersion within a nanocomposite. Interactions between the matrix and the filler result in the establishment of an interface between the matrix and the filler. The strength of nanocomposites is largely determined by these interfaces.

## Interfacial Bonding in Nanocomposites:

For good mechanical qualities, the nature of the bonding between the reinforcement and the matrix phase is critical. The creation of a weak interface is caused by Van der Waal's interactions between the matrix and reinforcement phases. When compared to electrostatic interactions, this weak interface cannot efficiently transmit load from matrix to reinforcement phase, but covalent bonding between filler and reinforcement provides a strong load transfer interface and significantly improves the characteristics of nanocomposites.

## Polymer Matrices

In polymeric nanocomposites, any form of polymer can be employed as a matrix phase. Polymers are chemically resistant and have excellent mechanical qualities.

## Types of Polymer Matrices

Thermoplastics, elastomers, and thermosets are the three categories of polymers.

### Thermoplastics

The intermolecular interactions that hold thermoplastic molecules together are quite weak. When heated, such materials soften and return to their former shape when cooled. The thermoplastic polymers include linear and somewhat branched polymers. Chain polymerization is used to make thermoplastic polymers. Thermoplastics are commonly employed due to their ease of shaping and reshaping into a variety of forms. Food packaging, insulation, vehicles, and credit cards, among other things, all utilize them. Thermoplastic polymers, such as polyethylene, is one example.

### Elastomers

Elastomers are rubber-like polymers that can be easily stretched when stressed. Stress causes the polymer to expand multiple times before returning to its normal proportions when the stress is removed. Cross-linked elastomers have a low cross-link density. Polymer chains can't travel indefinitely, although they do have some mobility. Elastomers include things like rubber bands.

### Thermosets

Heating thermosetting polymers does not allow them to be reshaped. The cross link density of thermosets is quite high. High modulus, strength, and stiffness are all characteristics of thermosetting polymers. Thermosetting polymers are commonly employed as matrices for PMNCs due to their advantageous features. Thermosetting polymers, unlike thermoplastics and elastomers, are more chemically inert. Thermosetting polymers include epoxy resins, phenolics, polyesters, and polyimides.

## Epoxy Resin

Epoxy resin is a thermosetting polymer with several epoxide groups.

## Characteristics of Epoxy Resin

Epoxy resins have great qualities and are frequently employed in industries as a result of these features. These qualities may be altered utilizing a variety of approaches such as the use of modifiers or fillers, resin mixing and curing agent selection. The following are some of the qualities of epoxy resins.

1. Light weight
2. Low viscosity
3. High electrical insulation
4. Good chemical resistance
5. High adhesive strength
6. Easy curing
7. Low shrinkage

## Curing Cycle of Epoxy Resin

Epoxy resins polymerize into a rigid, crosslinked three-dimensional solid when mixed with an appropriate curing agent or when a catalyst is used. Each epoxy system's curing cycle is empirically tuned. The temperature cycle for curing is determined by the curing chemical or catalyst employed. The accelerators, concentration of curing agent and catalysts affects the curing cycle. For polymerization, the stoichiometry of the curing agent (or hardener) and epoxy resin is critical. Although much effort has been done to understand the cure process, more study is still being done in this field.

## Strengths of Epoxy Resin

- Epoxy resin has a simple curing mechanism, in which it transforms from a liquid to a durable, hard solid when an appropriate curing agent is added.
- During the transition mechanism, i.e. from liquid to solid, no by products are generated.

- Between the curing agent and the epoxy resin, there is a stoichiometry.

## Epoxy Resin's Limitations

Due to the following qualities, the usage of epoxy resin is restricted:

- Not enough Strength
- Modulus is low

The above mentioned limitations can be removed by using suitable type of additive other than hardener than can change its characteristics like we can use nanomaterials like carbon nanotubes for this purpose as their strength and properties are well tested and defined.

## Epoxy Resin Applications

The following are some of the Epoxy Resin applications:

- For the repair of plastic and metal boats and other similar items.
- As adhesives; e.g. epoxy is used to connect the bristles of a paintbrush.
- For the production of molds, stamping dies, patterns, and tooling as a casting compound.
- In electrical equipment as an insulating substance.
- As a sealant compound, such as the construction of buildings and highways.
- Epoxies are also utilised in applications that demand a high level of chemical resistance.

### Epoxy as a matrix for Fiberglass

Epoxy/clay nanocomposite strengthened with high-strength glass fiber has outstanding perspective for commercial applications in automotive and aircraft industries because of their capability to improve mechanical features and reduced component weight.

## Uses and Advantages of composites

- Carbon fiber/Glass fiber and organic matrix-based composites are progressively being used in spacecraft and aircraft industries because of remarkably high strength, modulus, lightweight, good fatigue life, high stiffness, and excellent corrosion resistance.
- Due to low density, low manufacturing cost, and outstanding mechanical and physical features, these materials have substituted metals mainly aluminum alloys in several aerospace applications.
- The multifunctional, lightweight, and easily manufactured structural constituents such as polymer matrix composites have been progressively utilized in aircrafts. The polymer matrix composite contradicts the enhanced fuel and cost maintenance of commercial airplane. Polymer matrix composites are usually favored over metals due to fatigue resistance, corrosion suppression, reduced part count.

# CHAPTER 3: METHODOLOGY

Brief methodology of project includes:

- PVA preparation
- Epoxy formation
- Glass fiber face sheet
- Single layered composite
- Testing

## 3.1 Materials/Instruments:

Following materials were used in our sample preparations:

**Table 1: Materials/Instruments used :**

| **Material/Instruments** | **Manufacturers/Suppliers** |
|---|---|
| Glass Fiber | Ransal Fiber Glass Engineering, Rawalpindi, Pakistan |
| Nomex Honeycomb | Kunshan Bihore Honeycomb Materials Technology Co., Ltd |
| Epoxy resin Aradur 5052 | Huntsman |
| Hardener Aradur 5052 | Huntsman |
| Carbon-Nanotubes | Bottom Up Technology Corporation |
| Electronic Balance | Shimadzu Co. Kyoto, Japan |

| | |
|---|---|
| Ultrasonicator | Branson Ultrasonics Co., USA |

## 3.1 Manufacturing of Nanocomposites

Nanocomposites are prepared using the Hand lay-up technique and mesh flow method as well.

Details of different batches having different combination of adhesives is given below:

**Table 2: Batches of different sandwich structures**

| Batch | Description |
|---|---|
| Batch 0 | 6-layered Blank Glass fiber face sheets with 5mm thick honeycomb (Nomex material) with Epoxy 5052 as adhesive. |
| Batch 1 | 6-layered Blank Glass fiber face sheets 5mm honeycomb (Nomex material) with “2-layered glass fiber sheet +Epoxy 5052 + 0.1% CNTs” as adhesive |
| Batch 2 | 6-layered Blank Glass fiber face sheets 5mm honeycomb (Nomex material) with “Epoxy 5052 + 0.1% CNTs” as adhesive |
| Batch 4 | 6-layered Blank Glass fiber face sheets with 5mm thick honeycomb (Nomex material) with “Adhesive film” as adhesive |

### 3.1.1 PVA Preparation

PVA in powdered form is mixed with water in a beaker. The mixture is stirred using magnet under 100°C temperature for about 4-5 hrs. It is then allowed to cool. PVA is applied on the working table with the help of a simple brush. It takes some time to become dry but this time can be decreased with the help of a dryer. Dryer helps the PVA to get dry in a very less time. PVA is used so that sample doesn't stick to the glass table after getting dry. If we don't use PVA, the sample will stick to the working table so strongly that it will be nearly impossible to remove the sample safely.

### 3.1.2 Preparation of Adhesive

The stoichiometry between the epoxy and the hardener is very important. For the optimal mechanical properties of resin, a certain ratio of hardener is mixed with the epoxy. These ratios have already been determined experimentally and available in different writings. In our case (Epoxy Aradur 5052), we calculate the total amount of epoxy + hardener (weight of glass fibers + 10g). Take 72% of this total mass as epoxy and add 28% Hardener. Hardener should be added to epoxy only when we are about to apply the resin. Hardener transforms the epoxy to solid form after sometime. Therefore, epoxy would become unusable if it has already been transformed to solid before applying.

Different types of adhesives are being used in this method i.e.

- Simple epoxy with hardener 5052
- Epoxy with the integration of Nano particles
- Epoxy with 2-layered Fiber glass and CNTs
- Adhesive Film

### 3.1.3 Adding the Carbon Nanotubes

After taking the required amount of epoxy, we add CNTs 0.1% of the total weight of Epoxy + Hardener and then magnetic stirring is done for half an hour. After that, sonicating machine is used for sonication. This is done before adding hardener to the adhesive. UV rays are thrown on the adhesive and in this way sonication is done for 1 hour. After that, CNTs gets evenly and fully mixed with the epoxy and ready to be use. We add hardener after sonication and mixing of CNTs just before applying on the sample.

### 3.1.3 Ultrasonicator

Ultrasonicator is used for proper mixing of Nano-Particles. The adhesive having the Nano-particles contained in a beaker is placed in Ultrasonicator having a level of water. It constantly throws UV rays on the beaker for 1 hours. This helps the homogeneous and thorough mixing of Nano-Particles in the epoxy.

### 3.1.5 Face sheets

Face sheet can be made by two methods.

- Hand Lay-up technique
- Mesh-Flow method

Detail of each method is given as;

- **Hand Lay up:**

  In this method each layer of the glass fiber is lapped with the epoxy (adhesive + hardener) with the help of a brush. Each face sheet contains six layers of glass fiber. In this method, the glass fiber sheets are cut in accordance with the sample dimensions. These six layers are placed one above the other with epoxy layer in between each layer. Hand lay-up is mostly used where the adhesive needs to be applied in to join face sheets with the honeycomb and in between the sandwich structure. One thing we have to take into account is the quick application of adhesive because hardener is already present in the epoxy and it will soon get solidify.

- **Mesh Flow Method:**

  In this method all six layers of the glass fiber are placed on one another and covered with the vacuum. One side of the vacuum was connected with the suction pump and the other end are connected with an open pipe. At both ends stopper valves were attached to control the epoxy flow.

  The open-ended pipe is fully dipped with the epoxy and the other end with the pump. After that the pump start and the epoxy flow through the other end. The epoxy is also directed in a certain parameter with the help of the mesh present on the top layer of glass fibers.

### 3.1.6 Single layered Composite

First, the adhesive is allowed to dry and the face sheets get ready after adhesive gets dry. These face sheets are combined on the upper & lower side with the honeycomb in between to make the light weight but high strength composite structure. The same adhesive is used to combine honeycomb and face sheets and the adhesive is allowed to dry again. To make sure face sheets and honeycomb combine properly, the sample is either put under vacuum or under the weight.

We have prepared the samples according to ASTM standards and we will be performing Flatwise tensile & 3-point bed tests on Universal Testing Machine (UTM). We used **ASTM C393** standard for “3-point flexural bending test for Core shear properties of Beam” (3x8 inches sized samples according to the standard). & used **ASTM C297** standard for “Flatwise tensile testing”

(2x2 inches sized samples according to the standard). Our research work is related to practical work involving preparation and testing of samples, so the software that we are going to use will basically analyze and compile the results (obtained through testing of samples) by drawing graphs. We have used "**Origin pro**" for compiling the results in the form of graphs and "**Comsol**" for a theoretical analyzation and comparison of experimental results.

**Figure : Adesive with CNTs getting dry under vacuum**

# CHAPTER 4: RESULTS AND DISCUSSIONS

## 4.1 3-Point Flexural Bending Test

We have performed 3-point bend tests on different samples having different combination of adhesives. We have tested 3 samples for each batch in order to achieve accuracy in the results. There is some research done on individual properties of CNTs and GNPs, their behavior in different environments but there is not enough research on use of these Nano-Particles as composites combined in the Glass Fiber Honeycomb sandwich panels using different combinations to improve the interfacial strength. Our different combination formula will surely prove to be valuable. Nan-particles have excellent mechanical properties but are not strong enough in the perpendicular direction of the orientation of fibers. But we are trying to see the effect of these particles when used in the honeycomb sandwich structure and improve the strength of interfaces in order to improve the overall strength of the structure.

We are also comparing these CNTs added sandwich structures with the blank/simple honeycomb sandwich structures to see the effect of adding the Nano-Particles and are also trying different combinations of 0.1% CNTs.

Following are the results obtained by performing 3-point bending tests on the 3x8 [in] samples:

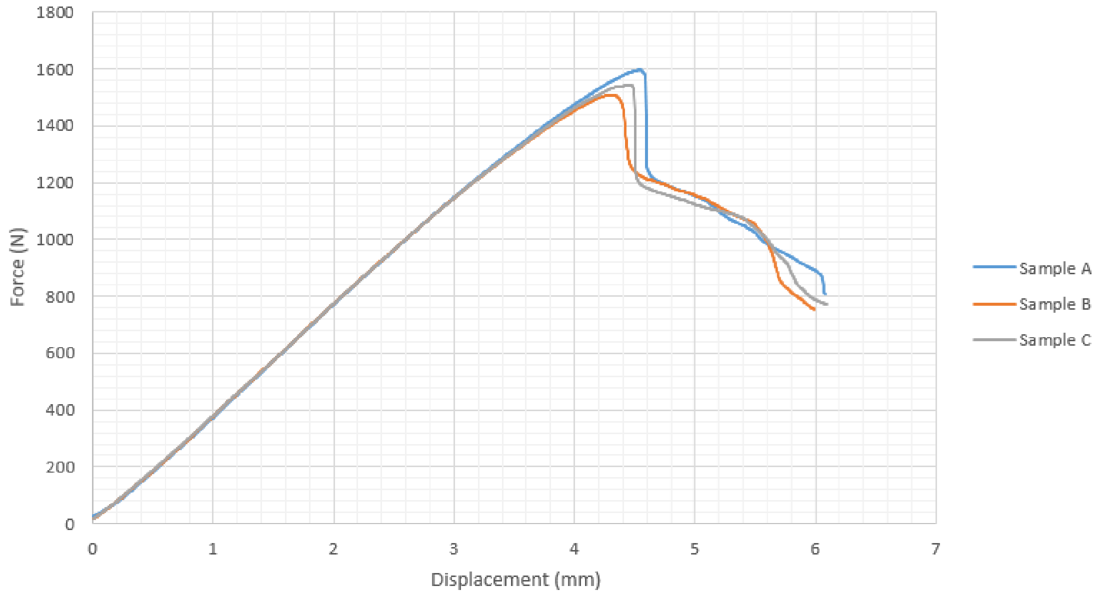



**Figure: Results of Batch 0**

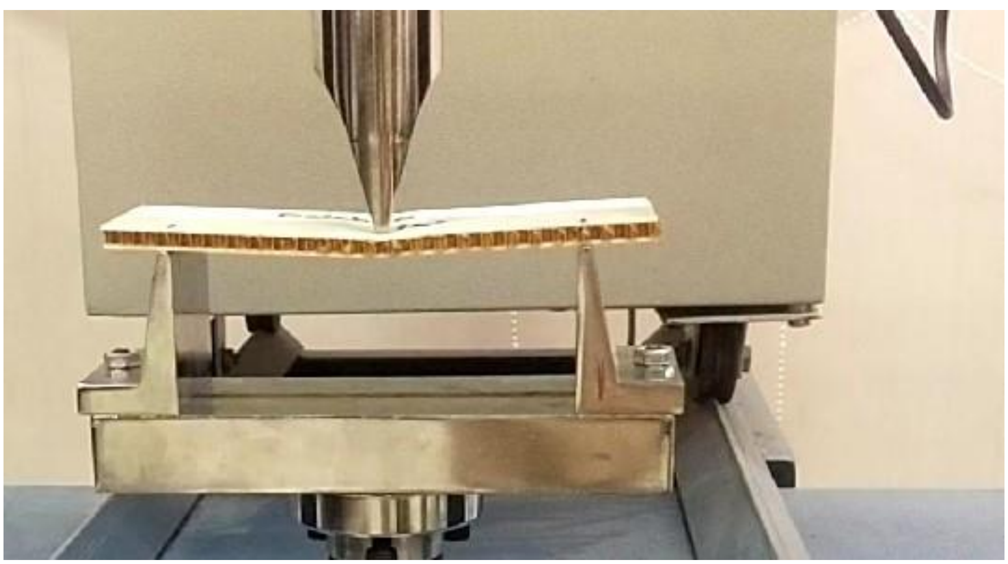


**Figure: 3-Point Bend testing of Batch 0**

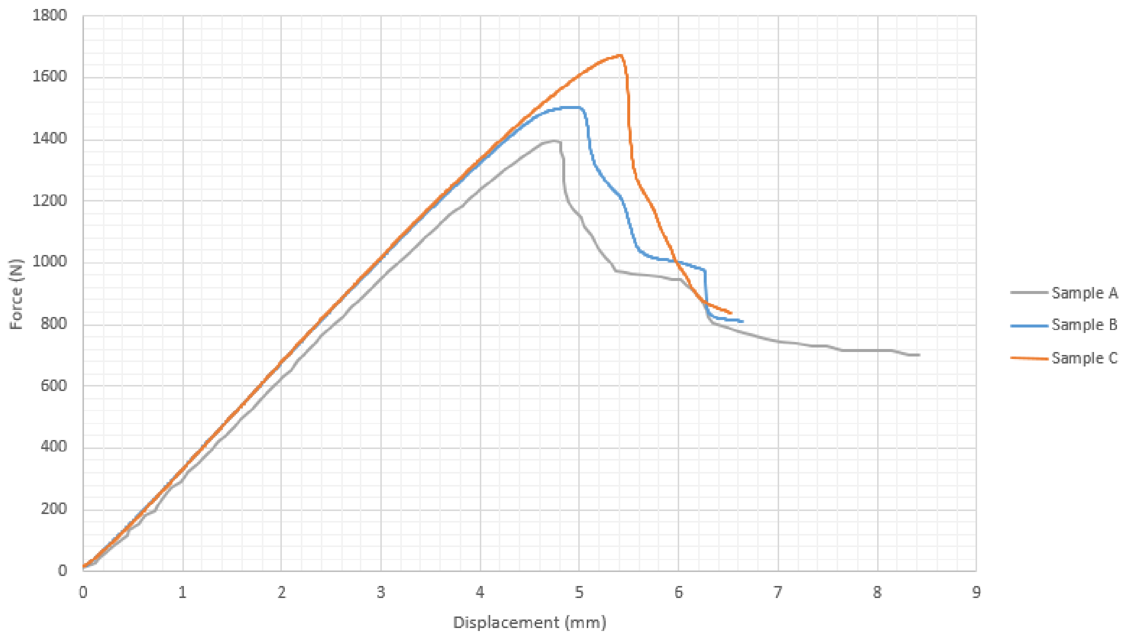



**Figure: Results of Batch 1**

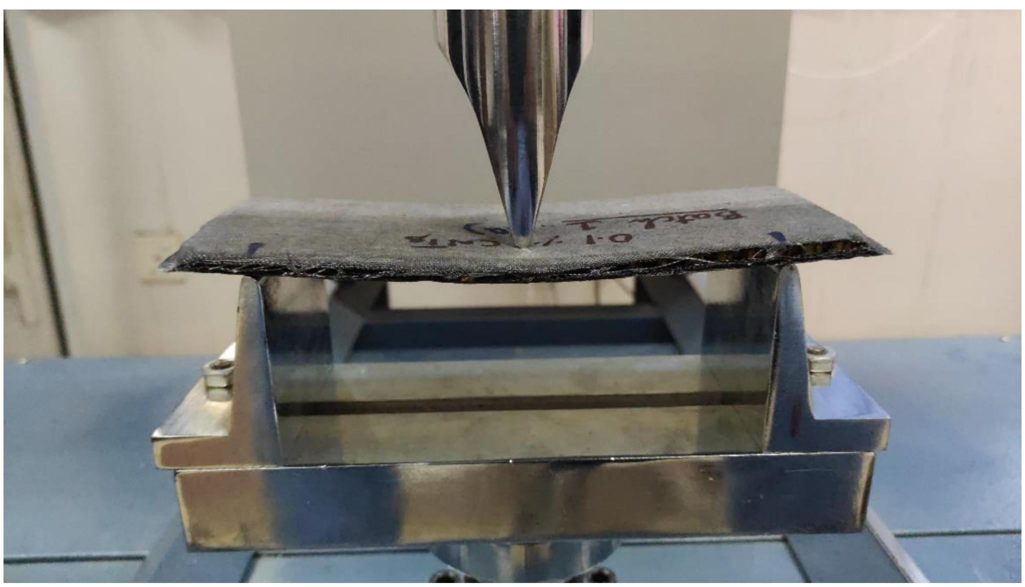


**Figure: 3-Point Bend testing of Batch 1**

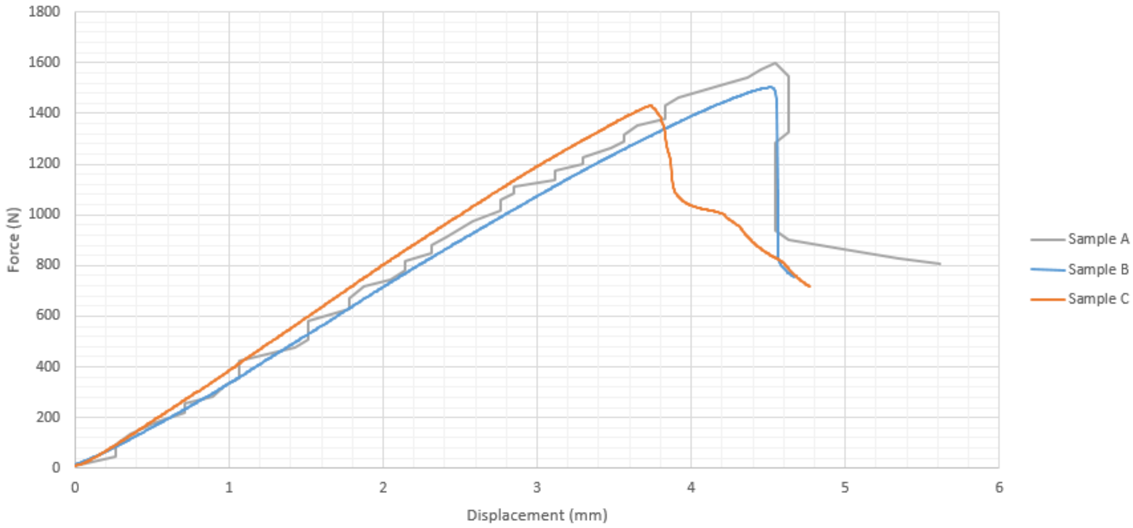



**Figure: Results of Batch 2**

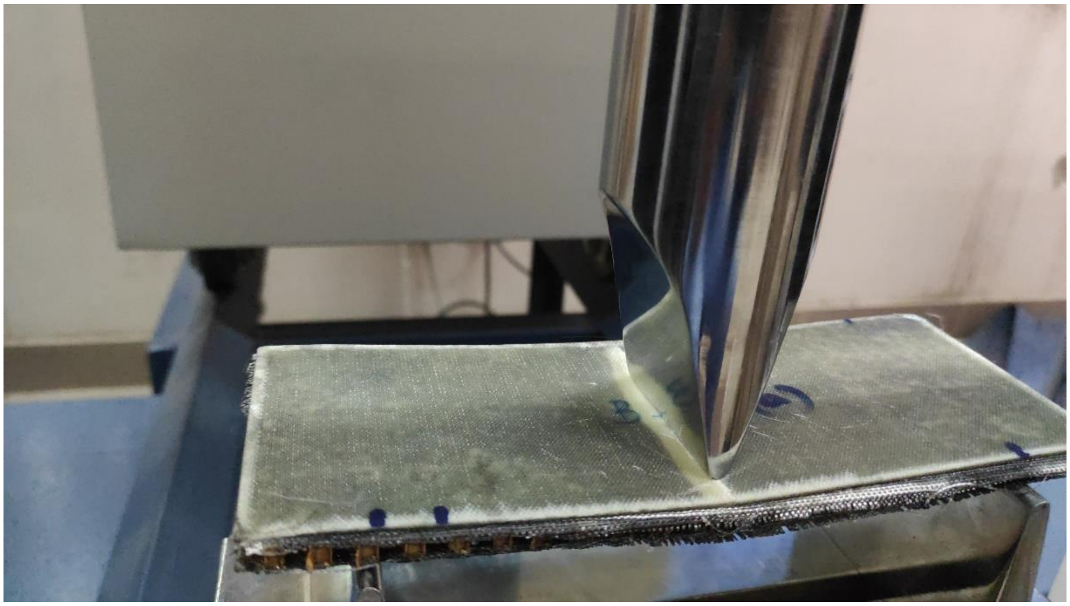


**Figure: 3-Point Bend testing of Batch 2**

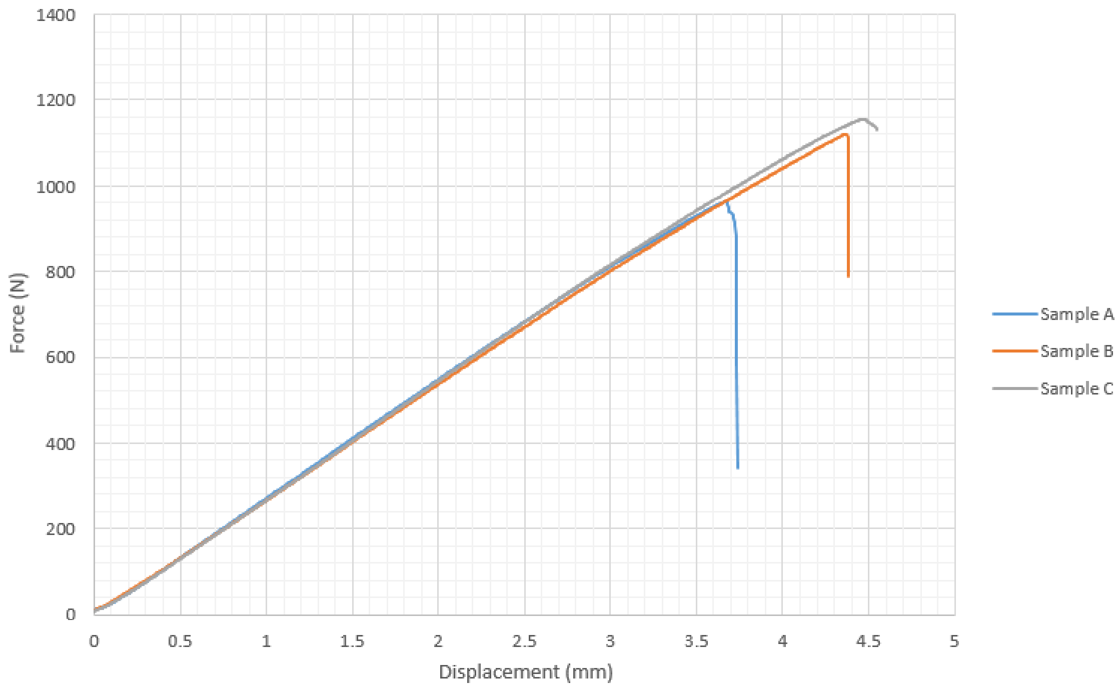



**Figure: Results of Batch 3**

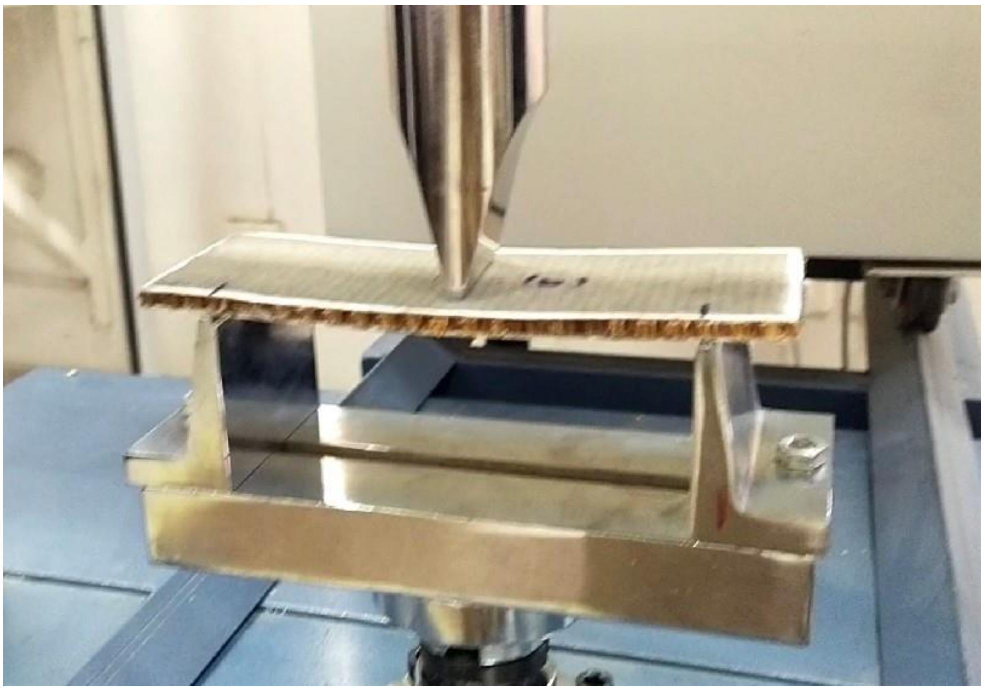


**Figure: 3-Point Bend testing of Batch 3**

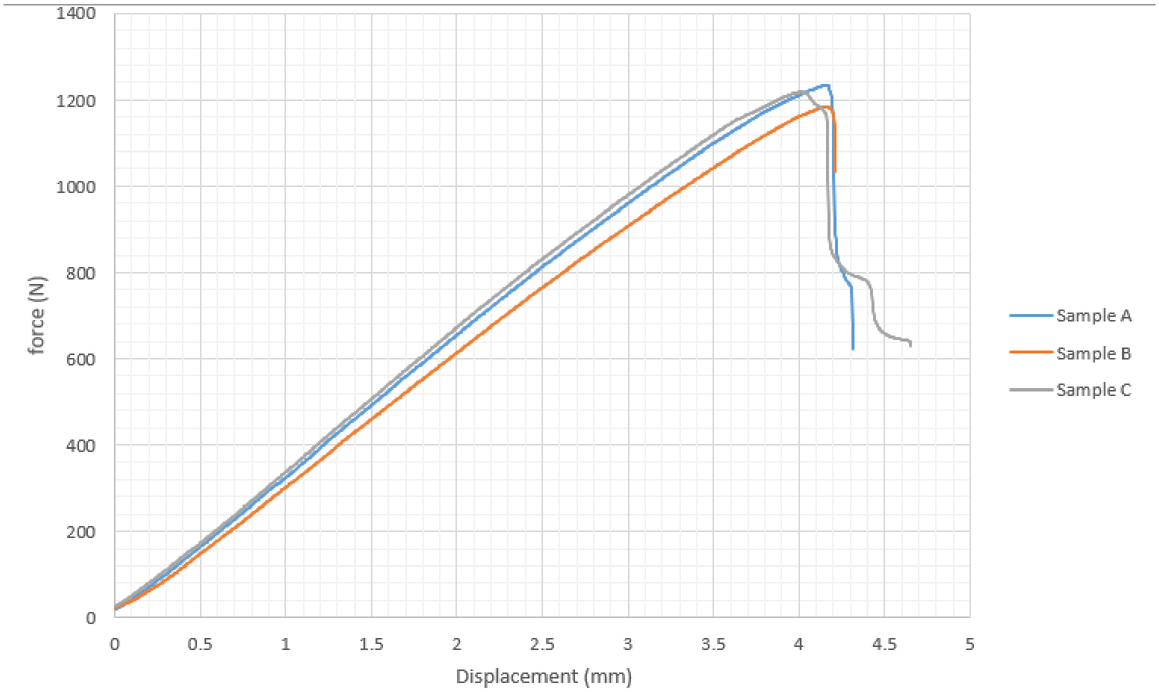



**Figure: Results of Batch 4**

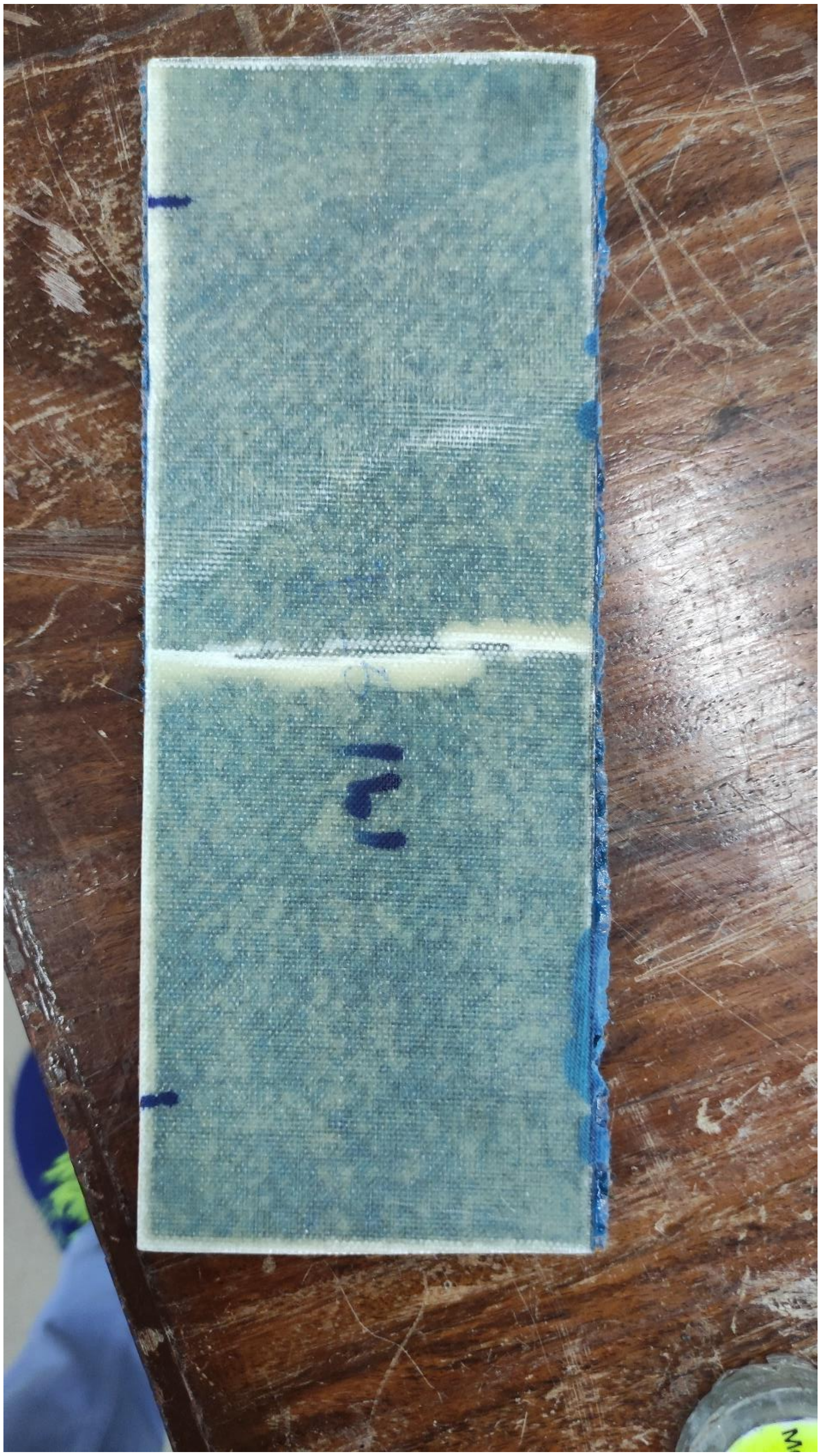


**Figure: 3-Point Bend testing of Batch 4**

**Figure 9: Sandwich structures without any Nano-Particles**

We have used a very small quantity of Nano-Particles in our samples. The strength offered by Nano-Particles is way too great than the simple samples. We are testing Nano-Particles for flatwise tensile and 3-point bend tests. We have mixed the Nano-Particles so carefully (using sonication and magnetic stirring) that makes it evenly distributed so that properties remains isotropic, but due to orientation of fibers, properties are stronger in the orientation of fibers but relatively less strong in the direction perpendicular to the orientation. But we have tried our best to make properties isotropic. These particles impart negligible weight and volume but the strength are other mechanical and thermal properties they provide are very significant. These are made of Carbon and Graphene. Carbon is itself a very strong element. It is already being used in structures and buildings for stability and strength. Graphene also possesses huge strength and is widely used in different areas of automobile and marine applications.

# CHAPTER 5: CONCLUSION AND RECOMMENDATION

The Composites always possess extra ordinary properties due to matrix and reinforcements combination, especially when composites made with core of honeycomb has light weight (density) but high strength because they are hollow from inside. This honeycomb core is not much thick but provides a very good strength. Due to high strength to weight ratio, these honeycomb core is super effective in giving strength to the structure without adding much weight. They offer strong resistance to bending forces. Glass fiber is very strong in tensile strength. When Glass Fiber and HC combine, their properties are combined giving a major boost to overall mechanical properties of the composite. The addition of Nano-Particles in the composite further strengthens the sandwich structure. Interfaces are the weakest and critical points of any structure. We have added Nano-particles in order to improve the strength of these interfaces so that these critical points also gain much strength. This will increase overall strength of the composite structure. We use different adhesives with little modifications to test the effect on the strength of the sandwich structure. The addition of Nano-particles provides extra strength. These are very small structure but provide very dominant strength to the structure. The comparison is between strength without the Nano-Particles and with the Nano-particles and then between the different Nano-Particles. GNPs and CNTs are two most strong Nano-Particles with both offering tremendous benefits and strength to the structure. The perfect application of these structures are in automobiles, turbine blades and aerospace applications due to the properties and benefits they offer.

### Recommendations:

It would be very good if we could further increase the percentage of Nano-Particles in the composite structure. We are using 0.1% Nano-Particles in our structures, which is good enough to provide a good strength but I think there should be more variation observed by increasing percentages of Nano-Particles and further try out different combinations to see the effect of increasing Nano-particles' concentration and finding out the optimal percentage of Nano-Particles that should be added for optimal properties and strength in accordance with the cost effectiveness. Each sample takes long enough to get prepared but it would definitely yield some great results with different combinations and increasing percentage of Nano-Particles.

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