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# ATTEMPTING AND INNOVATIVE POLYMER USING ARALDITE AW 106

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## INTRODUCTION

The project on the topic "Epoxy Resin Composites" is my attempt to gain in depth knowledge about composites. Epoxy resins were simultaneously developed in USA and Europein 1930's. Credit is most often attributed to Pierre Castan of Switzerland and S.O. Greenlee of the USA who investigated the reaction of bisphenol-A and epichlorohydrin. The first epoxy formulations were used as coatings and casting compounds while today the spectrum of their applications has widened to a great extent.A composite material is a material produced using at least two constituent materials with fundamentally unique physical or chemical properties that, whenjoined, create a material with qualities not quite the same as the individual segments.

Epoxy used in this experiment was Araldite AW 106 which was being cured with help of resin HV 953 U. This grade of epoxy is generally used as adhesives. The idea behind this research project was not constricted to analysis but was also being inspired by the zeal to develop a material with greater strength that can affirm a much stronger bond between the surfaces.

## EXPERIMENTATION

## MATERIAL REQUIRED

### EPOXY RESIN (AW 106)

It was bisphenol-A based resin containing some percentage of bisphenol-F as well.. This grade is specifically used as adhesive especially in furniture industry. It was quite irritating on the skin.

### HARDENER (HV 953 U)

It was mainly composed of polyaminoamide. The hazardous components included N(3-dimethylaminopropyl)-1,3 –propylenediamine. It was primarily used as a crosslinker ("hardener") in epoxy curing.It was a dense dark yellow viscous liquid which was poured in equal volumes as compared to that of the epoxy resin. This hardener was intended to be used with above mentioned grade of epoxy.

### KEVLAR FIBERS

The para aramid fibers were used as fillers for the reinforcement of the composite material that were to be tested. These were yellow colored fibers with good strength and tenacity. These were cut into an average length of 0.4 cm or 4 mm. The idea behind keeping the length short was reinforcement of the composite to a greater extent. The diameter was considered to be in the range of $10^{-1}$ mm.

### NYLON 6,6FIBERS

Nylon 66 is made of two monomers each containing 6 carbon atoms, hexamethylenediamine and adipic acid, which give nylon 66 its name. It was a green color fiber with fibers ranging upto $10^{-1}$ mm in diameter. To keep the aspect ratio same average length was kept to be 4 mm. The purpose of keeping the aspect ratio same was to compare the extent up to which the fibers reinforce a particular material, for example epoxy.

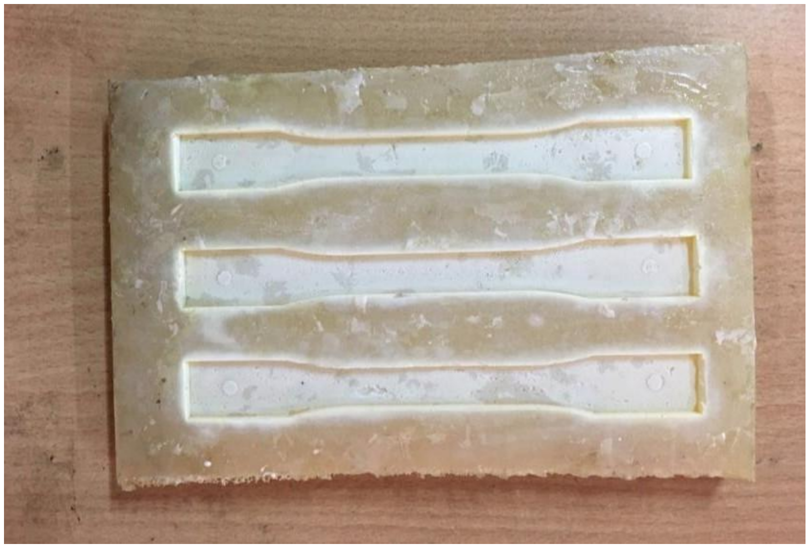
## APPARATUS REQUIRED

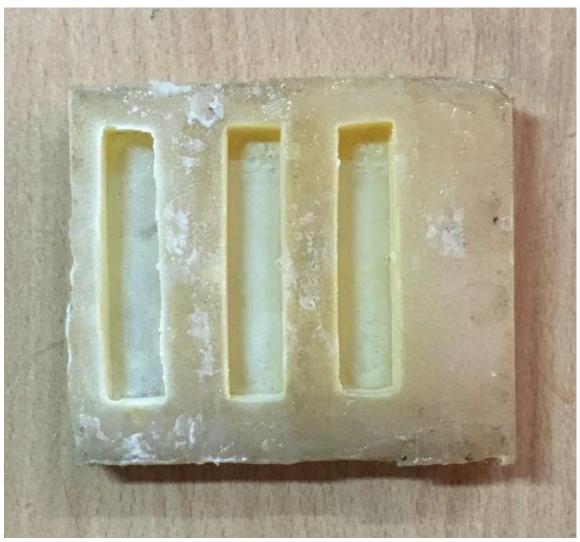
### Silicon Moulds

The moulds used were silicon based that provided the required dumb bell shaped cavity to prepare the standard samples for tensile testing. The dimensions of the mould were as follows:

- Thickness: 3.85 mm
- Width: 13.4 mm
- Length: 94.33 mm

Also standard cuboidal samples were prepared for 3 point flexural testing of the samples. The images below shows the moulds used.





# PROCEDURE

## FORMATION OF REINFORCED EPOXY SAMPLES

1:1(by volume) was the ratio maintained for resin and hardener. The epoxy resin was poured out in two separate beakers at a time. The epoxyin both the beakers is weighed and in accordance with the reading, the weight of the fibers to be used as fillers was calculated. The fibers were chopped to an average length of 4 mm. These chopped fibers were added to the resin very slowlyin small quantities so as to prevent the fibers from sticking to each other. The glass rod was used to disperse the fibers in the matrix. After stirring the contents for about 4-5 minutes, hardener was added to the beaker in equal volume as the resin. The contents are stirred and mixed manually but at a very high speed using a glass rod. The fibers sticking to the rod are removed with the help of clipper and again added to the mixture. The contents are stirred unless we obtainhomogeneous one phase mixture. The mixture is carefully filled into the cavity of the mould (being sprayed with a silicon spray prior to its filling) and left undisturbed for a day to cure completely. The procedure was adopted to prepare epoxy samples being reinforced with 0.1%, 0.5% and 1% kevlar and nylon fibers by weight.The fully cured samples were tested for tensile and flexural strength.

## PRODUCT

(A) (B)

(C) (D)

**(A) : KevlarReinforced Samples, (B): Kevlar and Nylon Reinforced Samples, (C): Kevlar Fibers 1cm in length, (D): Mixing Epoxy Resin and Hardener**

## CHARACTERIZATION TECHNIQUES

## TENSILE STRENGTH

### INTRODUCTION

Ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength,is the limit of a material or structure to withstand loads having a tendency to lengthen, rather than compressive strength, which withstands loads having a tendency to lessen estimate. As it were, elasticity opposes strain (being pulled separated), though compressive strength opposes pressure (being pushed together). Extreme elasticity is estimated by the maximum stress that a material can withstand while being extended or pulled before breaking.

It is given by the formula:

$$\text{Tensile Strength} = \text{Maximum load at break} \div \text{Area}$$

Its S.I. unit of measurement is pascal or $\text{newton.meter}^{-2}$

**INSTRUMENTS REQUIRED**

**UNIVERSAL TESTING MACHINE:**

A universal testing machine (UTM), also known as a universal tester is a machine whose basic purpose is totest the tensile strength, flexural strength and compressive strength of materials. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures (in other words, that it is versatile).

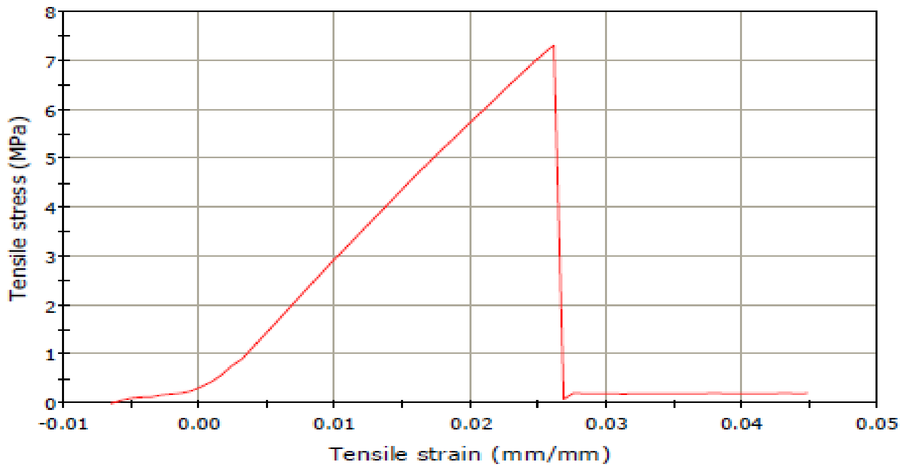
**PROCEDURE**

The dimensions of the samples were measured using a scale. These dimensions are fed in the computer and the sample is clamped in the UTM machine. The test is carried out at an extension rate of 10mm/min. Once the sample breaks, the test is stopped and precisely calculated data is obtained. This data can be compared and analyzed.

**RESULTS**

**FOR 1% (BY WEIGHT) REINFORCED FIBERS:**

1. Kevlar Reinforced



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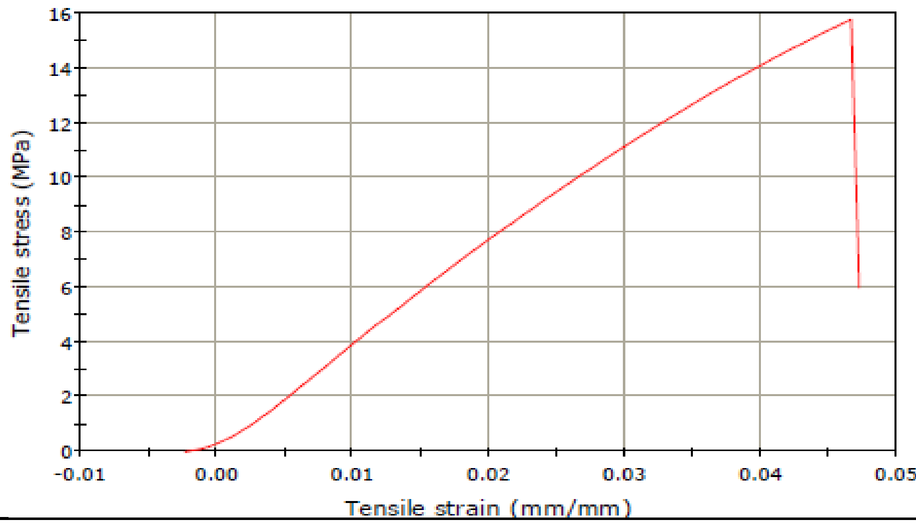
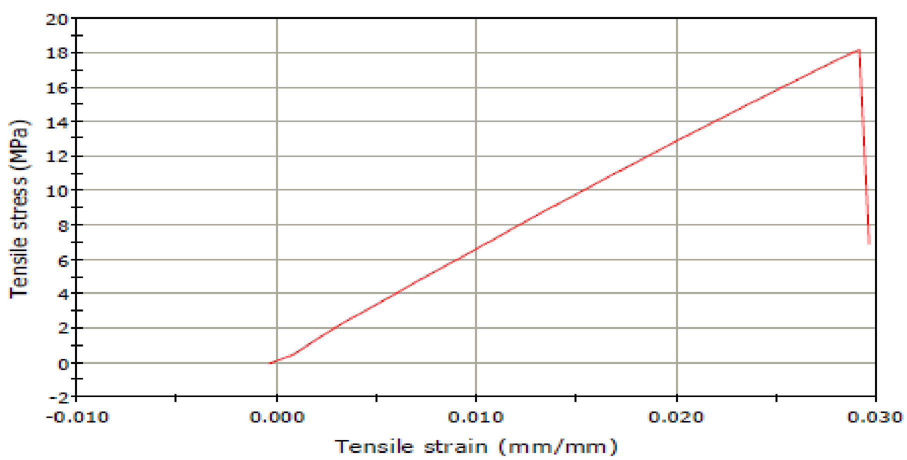
| | |
|---|---|
| Tensile Strain at Break (mm/mm) | 0.04485 |
| Load at Maximum Extension (N) | 10.52523 |
| Area (mm²) | 48.75000 |
| Tensile Strength (MPa) | 0.21590 |

2. Nylon Reinforced




| | |
|---|---|
| Tensile Strain at Break (mm/mm) | 0.04669 |
| Load at Maximum Extension (N) | 311.14325 |
| Area (mm²) | 52.00000 |
| Tensile Strength (MPa) | 5.98352 |

3. Epoxy (Not Reinforced)



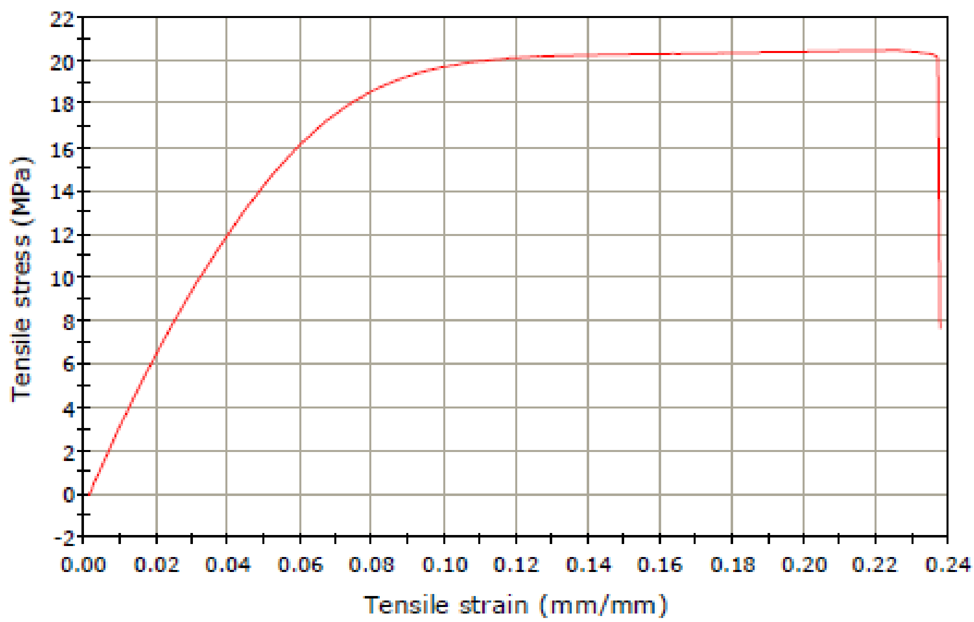
| | |
|---|---|
| Tensile Strain at Break (mm/mm) | 0.02914 |
| Load at Maximum Extension (N) | 348.80820 |
| Area (mm²) | 52.00000 |
| Tensile Strength (MPa) | 6.70785 |

**INFERENCE:**

It was expected that the tensile strength of the kevlar reinforced epoxy would be the highest while that of non-reinforced epoxy would be the lowest. But the results were completely opposite to what were expected with the non reinforced epoxy showing the highest tensile strength preceded by nylon reinforced. The kevlar reinforced epoxy showed the lowest strength. The probable reason for such unexpected results is the improper dispersion of the fibers in the matrix phase i.e. epoxy. Most of the fibers were stuck to the glass rod and hence we could also infer that maximum incorporation was less than 1%. So we reduced the percentage of fibers incorporated into matrix because 1% incorporation was not possible.

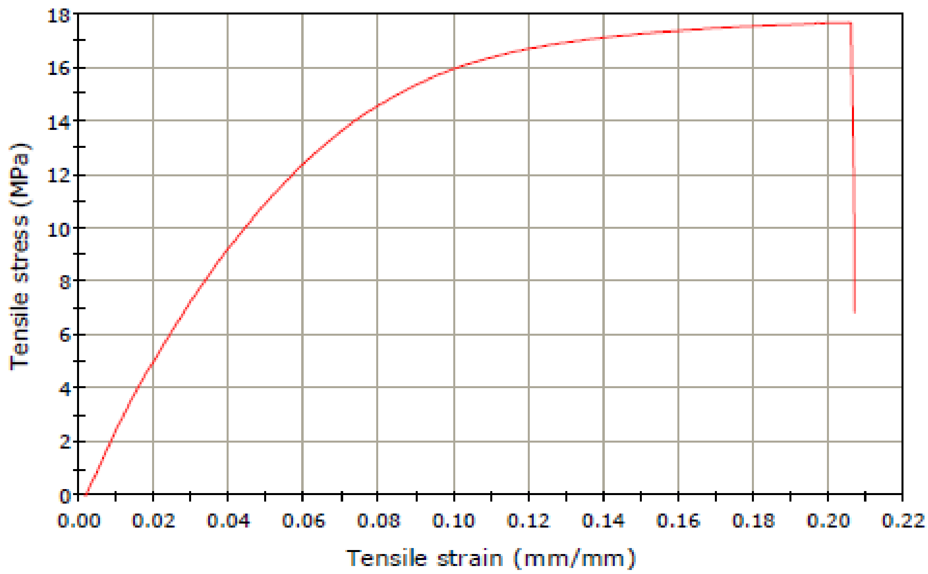
**FOR 0.1% (BY WEIGHT) REINFORCED FIBERS:**

1. Kevlar Reinforced



| | |
|---|---|
| Tensile Strain at Break (mm/mm) | 0.23706 |
| Load at Maximum Extension (N) | 451.03258 |
| Area (mm²) | 58.00000 |
| Tensile Strength (MPa) | 7.67062 |

2. Nylon Reinforced



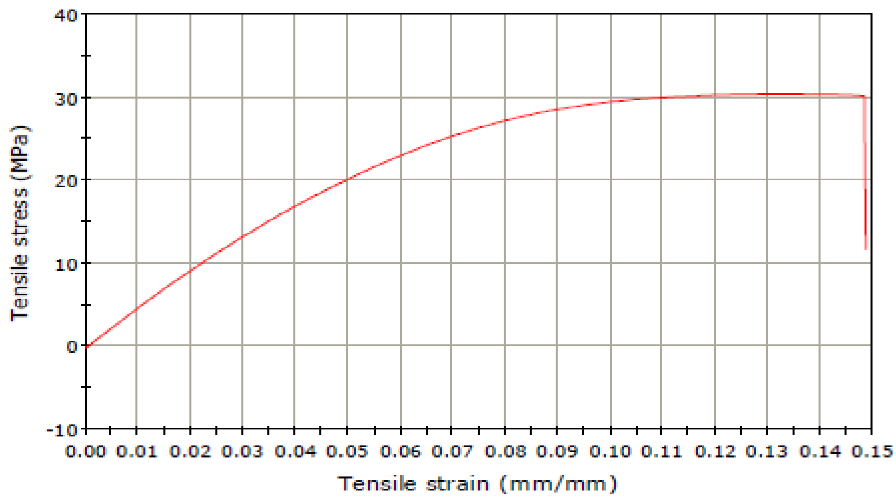

| | |
|---|---|
| Tensile Strain at Break (mm/mm) | 0.20676 |
| Load at Maximum Extension (N) | 444.80292 |
| Area (mm²) | 65.00000 |
| Tensile Strength (MPa) | 6.84312 |

**INFERENCE:**

At 0.1% reinforcement, the results were such that the Kevlar reinforced epoxy showed the greatest tensile strength while that of the Nylon reinforced epoxy was lesser which reflected that incorporation was being done properly. The results were as expected.

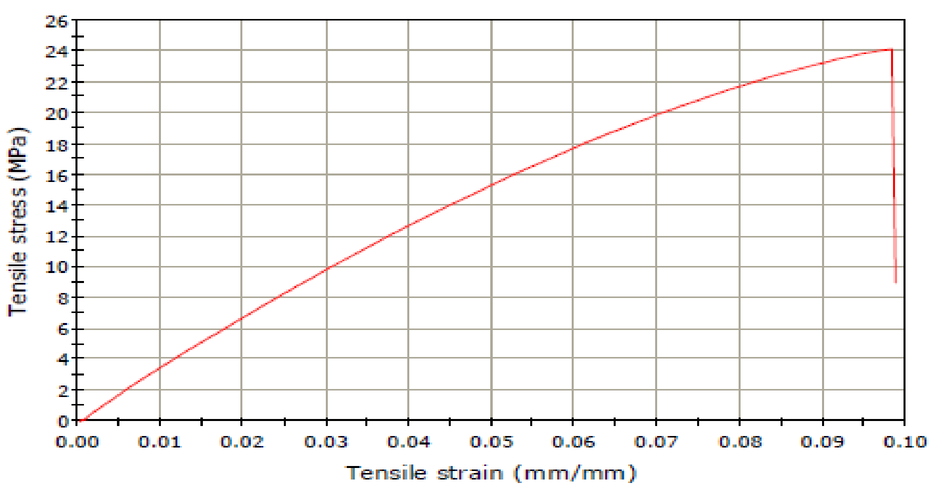
**FOR 0.5% (BY WEIGHT) REINFORCED FIBERS:**

1. Kevlar Reinforced




| | |
|---|---|
| Tensile Strain at Break (mm/mm) | 0.14837 |
| Load at Maximum Extension (N) | 761.58904 |
| Area (mm²) | 65.00000 |
| Tensile Strength (MPa) | 11.71675 |

2. Nylon Reinforced



| | |
|---|---|
| Tensile Strain at Break (mm/mm) | 0.09831 |
| Load at Maximum Extension (N) | 502.57021 |
| Area (mm²) | 56.00000 |
| Tensile Strength (MPa) | 8.97447 |

**INFERENCE:**

For 0.5% reinforcement, the strength of the samples was as expected with kevlar reinforced epoxy gaining the highest strength preceded by nylon reinforced epoxy. From this we could inferthat 0.5% reinforcement was an optimum reinforcement for epoxy matrix and hence we gained the results as per the expectations. From this we additionally induced that level of fiber incorporation impacts the way the reinforecement is being given to the matrix phase. The strength increment in case of kevlar was extraordinary.

## FLEXURAL STRENGTH

### INTRODUCTION

Flexural Strength, also known as modulus of rupture , bend strength or fracture strength is a material property defined as the stress in the material just before it yields in a flexural test.

### INSTRUMENTS REQUIRED

### UNIVERSAL TESTING MACHINE:

A universal testing machine (UTM)is a machine whose basic purpose is totest the tensile strength, flexural strength and compressive strength of materials. The "universal" part of thename reflects that it can perform many standard tensile and compression tests on materials, components, and structures (in other words, that it is versatile).

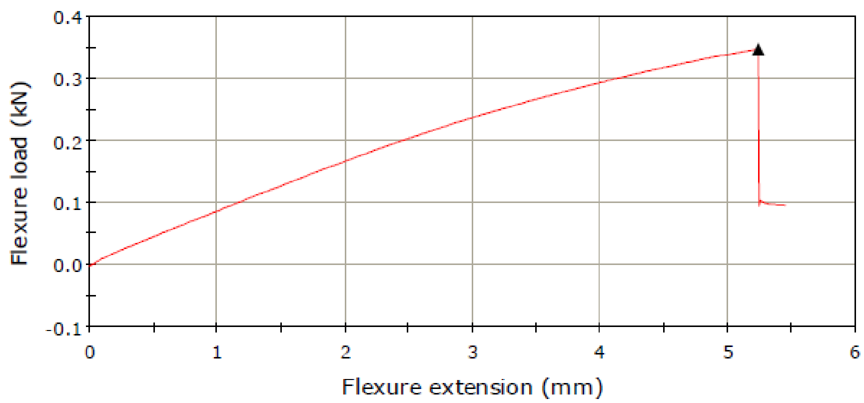
### PROCEDURE

The dimensions of the samples were measured using a scale. These dimensions are fed in the computer and the sample is clamped in the UTM machine. The test is carried out at an extension rate of 10mm/min. Once the sample breaks, the test is stopped and precisely calculated data is obtained. This data can be compared and analyzed.

**RESULT**

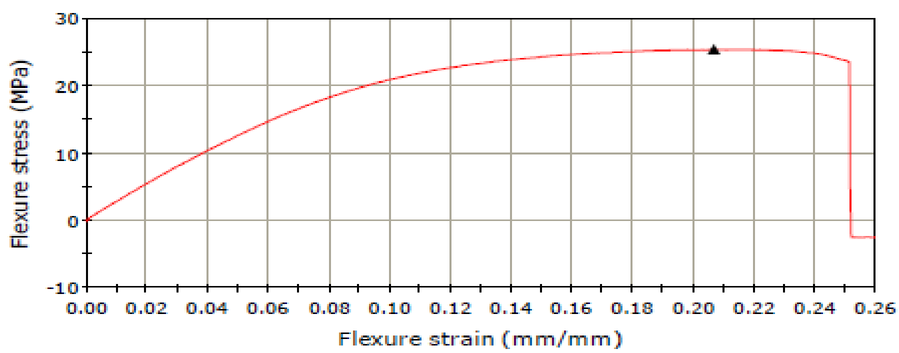
**FOR 1.0% (BY WEIGHT) REINFORCED FIBERS:**

1. Kevlar Reinforced



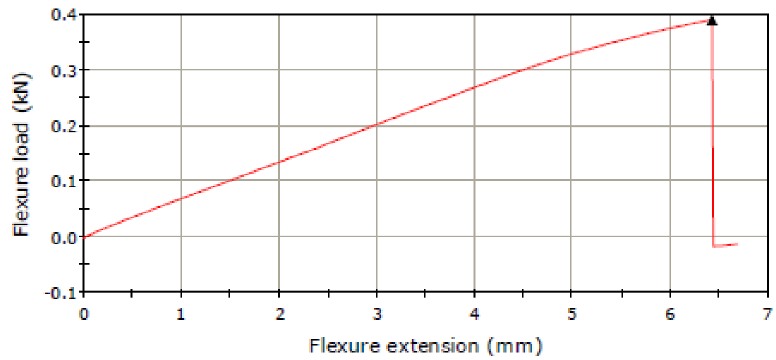

| | |
|---|---|
| Flexure Strain at Maximum Flexure Load (%) | 8.17406 |
| Maximum Flexure Extension (mm) | 5.44938 |
| Flexural Strength (MPa) | 25.68398 |

2. Nylon Reinforced




| | |
|---|---|
| Flexure Strain at Maximum Flexure Load (%) | 25.97318 |
| Maximum Flexure Extension (mm) | 15.58391 |
| Flexural Strength (MPa) | 25.41887 |

3. Non Reinforced Epoxy



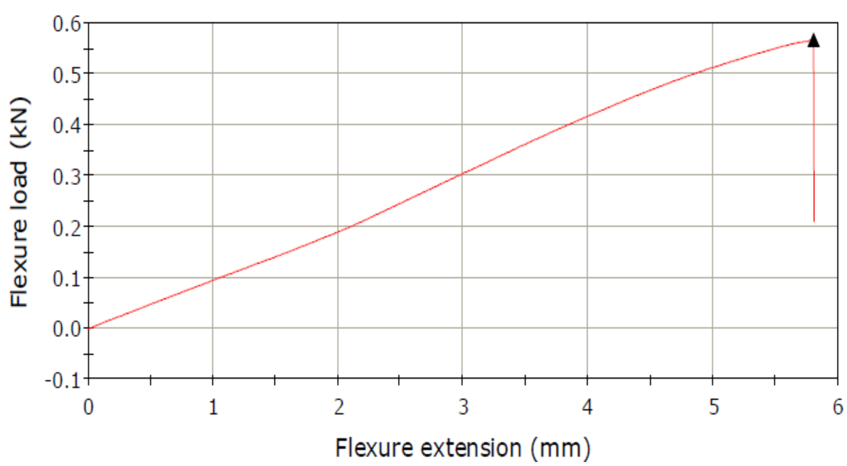

| | |
|---|---|
| Flexure Strain at Maximum Flexure Load (%) | 10.02773 |
| Maximum Flexure Extension (mm) | 6.68516 |
| Flexural Strength (MPa) | 28.89045 |

**INFERENCE:**

Although the strength of Kevlar reinforced epoxy was more than that of nylon reinforced epoxy but their strength was much lesser than non reinforced epoxy. The reason may be due to improper dispersion.

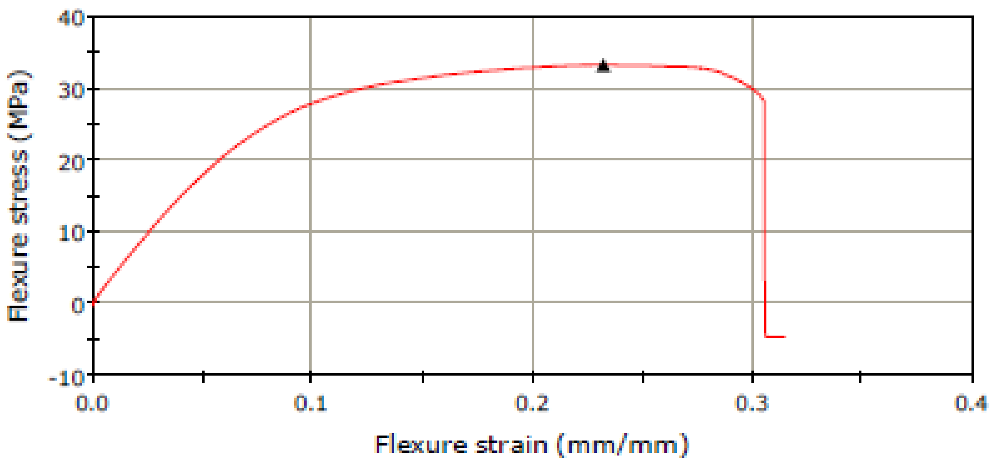
**FOR 0.1% (BY WEIGHT) REINFORCED FIBERS:**

1. Kevlar Reinforced



| | |
|---|---|
| Flexure Strain at Maximum Flexure Load (%) | 8.70820 |
| Maximum Flexure Extension (mm) | 5.80547 |
| Flexural Strength (MPa) | 41.98713 |

2. Nylon Reinforced



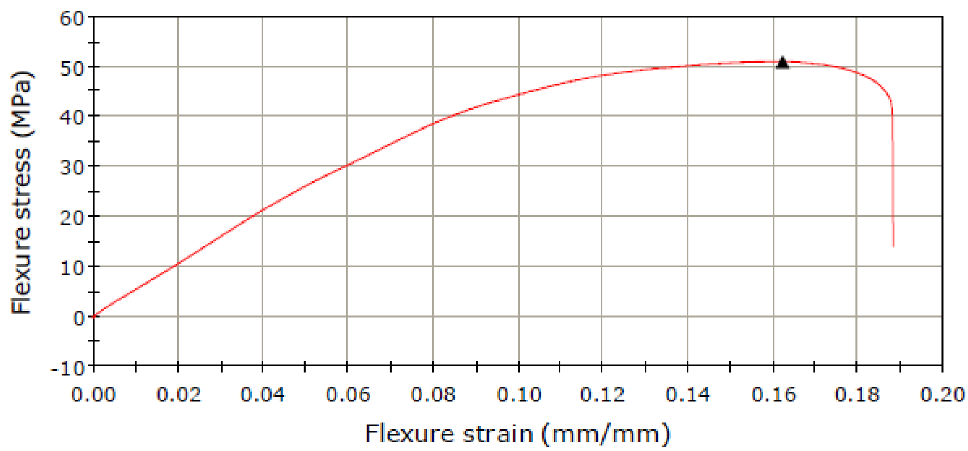

| | |
|---|---|
| Flexure Strain at Maximum Flexure Load (%) | 31.49349 |
| Maximum Flexure Extension (mm) | 18.89609 |
| Flexural Strength (MPa) | 33.18719 |

**INFERENCE:**

With proper dispersion of fibers in the matrix phase, we could get the results as were expected. By reinforcing the epoxy with kevlar and nylon fibers, the flexural strength increases with kevlar gaining the maximum flexural strength.

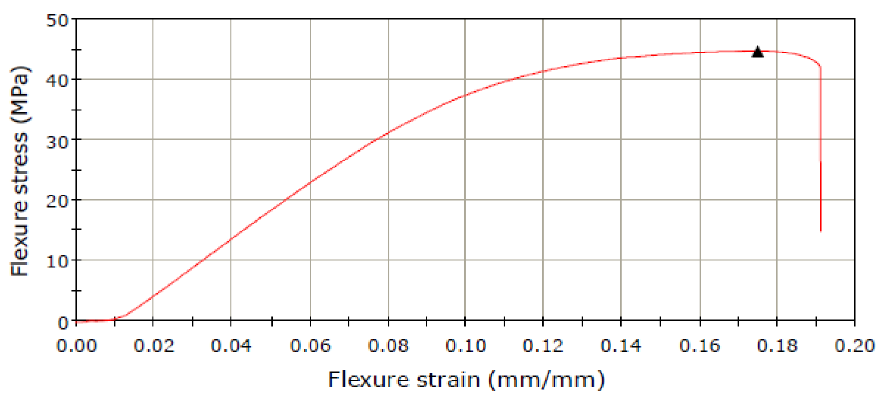
**FOR 0.5% (BY WEIGHT) REINFORCED FIBERS:**

1. Kevlar Reinforced




| | |
|---|---|
| Flexure Strain at Maximum Flexure Load (%) | 0.16215 |
| Maximum Flexure Extension (mm) | 11.29062 |
| Flexural Strength (MPa) | 50.95977 |

2. Nylon Reinforced



| | |
|---|---|
| Flexure Strain at Maximum Flexure Load (%) | 19.10729 |
| Maximum Flexure Extension (mm) | 11.46438 |
| Flexural Strength (MPa) | 44.69665 |

**INFERENCE**

Increasing the proportion of fibers in the matrix, strength of the composites is increased. This shows that the dispersion was good and optimum. Hence we could infer that this was anoptimum proportion of reinforcement.

## DISCUSSION

The above given data clearly implies that reinforcing epoxy with nylon and kevlar with proper dispersion of the fibers in the matrix phase definitely leads to an enhancement in the mechanical strength of epoxy. The incorporation of fibers like nylon and kevlar with good Young's Modulus devote their strength to epoxy in the direction in which the fibers are incorporated in the matrix.

## APPLICATIONS

- The reinforced epoxy hence produced could be used in the areas that demand greater flexural strength. The beams used to support the roofs can be one of its applications.
- Can be used as a better performance adhesive with greater adhesion. This can be done by chopping the reinforced epoxy material and mixing it with adhesive. This way it will increase the strength of adhesives in the direction in which fibers have been reinforced
- Coatings of furniture and weak surfaces.
- Could be used as sealants with improved properties
- Structural or engineering for construction of automobiles, boats, aircrafts, etc
- Integral part of electronic industry, used in over molding transistors, PCB's, integrated circuits, etc.

## CONCLUSION

The whole project was based on my endeavor to gain in depth knowledge in the field of epoxy composites. With the guidance of myprofessors and by virtue of myzeal, I successfully established my project and studied the impact of reinforcement on epoxy. By using different fibers (Nylon and Kevlar) and varying the percentage of reinforcement in epoxyI collected enough data so that I can conclude my result based on the change in the mechanical strength of epoxy.While I expected an increase in the properties, it was made being clear by the experimentation data that reinforcement does always enhance the properties but may lead to deterioration of the original properties of matrix

Keeping the percentage of reinforcement constant, I could well observe that the strength devoted by kevlar is greater than the nylon fibers due to higher tensile modulus/ tenacity of the Kevlar.On varying the proportion of reinforcement there was an appreciable increase in the mechanical properties. Increasing the reinforcement further leads to an improper dispersion of the fibers leading to degradation of the properties. Hence by virtue of my research project and analysisI could learn how reinforcement by the fibers brings about a change in the mechanical properties. By means of experimentation, I also inferred that 0.5% reinforcement was optimum for epoxy and beyond this percentage dispersion becomes difficult; hence mechanical propertiesdeteriorate.

During the course of my project, I earned a golden opportunity to look beyond our curriculum and open our minds to look into the field of polymers with a whole new perspective. The area I explored is full of opportunities and has many innovations still in queue to be flashed in front of the world for the obvious good of humanity.