International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

Investigation of Tensile, Compression and Fastening Properties for the Glass and Hemp Polymer Hybrid Composites

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Abstract **- Hemp fibre-reinforced polyester composites were prepared using a Hand layup technique (HLT) and the tensile and compression behaviour investigated. Flexural stress at break and flexural modulus showed an increasing trend with fibre content. tensile strength was found to decrease at low fibre content, then gradually increase with further addition of fibres. a strong interfacial adhesion between hemp and glass fibres was obtained using chemically modified hemp (textile hemp). Increased bonding between fibres and matrix did not affect the flexural stress at break of the composite but was detrimental to toughness. This behaviour was ascribed to a change in the mode of failure, from fibre pull-out to fibre fracture, resulting in a marked reduction in the energy involved in the failure of the composite, leading to a more brittle material.**

Key points :- Glass Fibers - Hemp Reinforced Composites - HLT - Flexural Stress Tensile Strength - Interfacial Bonding .

1. INTRODUCTION:-

Polymer matrix composites is also known as FRP - Fiber Reinforced Polymers (or Plastics) these materials use a polymer-based resin as the matrix, and a variety of fibers. Fabric reinforced composites have become the necessary materials in various engineering applications like aerospace, marine and automobile engineering, because of their light weight, high strength, stiffness and resistance to high temperature. In the recent years, the use of composites in marine applications is widespread. The major advantages of fiber-reinforced plastics over metals are resistance to the marine environment, particularly the elimination of galvanic corrosion and the ease of tailoring structures, which are fabricated by molding processes.

Composite materials have been widely used, in the civil and ocean engineering fields as well as in aerospace and automobile industries. In many practical applications, it is virtually impossible to make a whole structure as a single body. Many structures are therefore manufactured in various parts that are connected through joints later . Because manufacturing the whole structure using only composites is not generally feasible. Therefore, the joint used in composite structures, with only a few exceptions, determines the structural efficiency because it usually becomes the weakest part of the structure .

For our work Hemp is the reinforcement material and it is one of the strongest and most durable of all natural textile fibers. Products made from hemp will outlast their competition by many years. Not only is hemp strong, but it also holds its shape, stretching less than any other natural fiber. This prevents hemp garments from stretching out or becoming distorted with use. Hemp may be known for its durability, but its comfort and style are second to none. The more hemp is used, the softer it gets. Hemp doesn't wear out, it wears in. Hemp is also naturally resistant to mold and ultraviolet light. Due to the porous nature of the fiber, hemp is more water absorbent, and will dye and retain its color better than any fabric including cotton. This porous nature allows hemp to "breathe," so that it is cool in warm weather. Furthermore, air which is trapped in the fibers is warmed by the body, making hemp garments naturally warm in cooler weather.

2. MATERIAL DETAILS AND SPECIMEN PREPARATION:-

Materials used for the experiment

SL. No	Reinforced Material	Reinforced material	Matrix material
1	Glass fiber/fabrics	Textile hemp fiber	L-12 lepoxy,K-6 hardener

2.1 Material

The most widely used artificial fiber is a glass fiber and natural fiber is a Hemp fiber is used as a reinforcement material and epoxy as matrix resin. Araldite is an adhesive selected for doing the adhesive joint in composite laminates. These materials are used in the present work.

2.2 Matrix material

The matrix material is used as a medium viscosity epoxy resin (LAPOX L-12) and a room temperature curing polyamine hardener (K-6).This matrix was chosen, since it provides good resistance to alkalis and good adhesive properties.

- *Epoxy resin*

Matrix polymer used in present study is Lapox L12 resin and K-6 hardener. We used epoxy resin with Lapox L12 resin. They bond practically to any material when inner support structures for additional tool stiffness are required. They are durable and won't rust and won't warp. They provide quick, easy and inexpensive modification for repair of valuable tools. These are low temperature curing resins, normally between 20 to 90 degree C, but some formulations are made for high temp curing. They are advantage of being used without solvent and curing without creating volatile by products and have low volume shrinkage. It's a thermosetting plastic and get hardened with the help of hardener K6. This hardener is room

temperature curing, low viscosity and commonly used for hand lay application. It gives rapid

cure at normal ambient temperature.

2.3 Reinforcement material

The reinforcements of this hybrid composite are glass fabric (330GSM) with 0.06mm to 0.07 mm of fiber diameter and Hemp fabric with 0.05 to 0.06 mm of fiber diameter. Glass fibers are used in marine aerospace and automobiles because of their high strength, low cost, high chemical resistance, and good insulating properties. Hemp has a poor resistance to sunlight exposure and it absorbs moisture. One remarkable property of Hemp is its high tensile strength and its fibers will not easily be torn or damaged.

- *Glass Fibers*

Glass fibers are amorphous and isotropic and are along, three-dimensional network of silicon, oxygen, and other atoms arranged in a random fashion. Its advantages include high strength, low cost, high chemical resistance, and good insulating properties. The drawbacks include low elastic modulus, poor adhesion to polymers, high specific gravity, sensitivity to abrasion reduces tensile strength, and low fatigue strength. The different types of glass can be produced are E-glass (electrical) - lower alkali content and stronger than A glass (alkali). Good tensile and compressive strength and stiffness, good electrical properties and relatively low cost, but impact resistance relatively poor.

- *Hemp*

Hemp fiber is one of the strongest and most durable of all natural textile fibers. Products made from hemp will outlast their competition by many years. Not only is hemp strong, but it also holds its shape, stretching less than any other natural fiber. This prevents hemp garments from stretching out or becoming distorted with use. Hemp may be known for its durability, but its comfort and style are second to none. The more hemp is used, the softer it gets. Hemp doesn't wear out, it wears in. Hemp is also naturally resistant to mold and ultraviolet light. Due to the porous nature of the fiber, hemp is more water absorbent, and will dye and retain its color better than any fabric including cotton. This porous nature allows hemp to "breathe," so that it is cool in warm weather. Furthermore, air which is trapped in the fibers is warmed by the body, making hemp garments naturally warm in cooler weather.

Properties of matrix and reinforcement

Properties	E-Glass Fabric	Epoxy (Lapox L-12)	Hemp Fabric
Density in g/cc	2.48	1.25	1.07
Tensile strength in MPa	3448	50 - 60	962
Compressive strength in MPa	30000	110 - 120	------
Modulus of elasticity in GPa	72.4	4.4 - 4.6	5.6 - 30.1
Coefficient of linear thermal expansion in μ/ºC	5	64 – 68	------

2.4 Adhesive material

Araldite is an epoxy adhesive selected for bonding the composite laminates. The major advantage of adhesive bonding is that fastening holes and fasteners which are a source of stress concentration and weight increase are no longer necessary. As a result the stress distribution in adhesive bonded joints is relatively uniform compared to that in mechanical joints.

3. EXPERIMENTAL WORK

The experimentation on the specimen was carried out according to the ASTM standards. The specimens were compression and tensely loaded in the universal testing machine until fracture occurs. Compression and Tensely loaded was applied uniaxially to the specimen. During the test load, displacement, stress, strain data was recorded for all specimens under all condition. In the present work tensile and compression test were carried out on specimens listed below

Tensile specimen

Compression specimen

Bolted lap joint specimen

Adhesive lap joint specimen

3.1 SPECIMEN PREPARATION BY HAND LAYUP TECHNIQUE

The laminates were fabricated by using hand lay-up technique with a stacking sequence of [0/90].In which required volume fraction is attained by adding the materials at required proportion. The matrix material is used as an epoxy resin (LAPOX-L12) and polyamine hardener (K-6). The reinforcements of this hybrid composite are glass fabric (330GSM) and Hemp fabric. The ratio of mixing epoxy and hardener is 10:1 by volume and required volume are directly measured in the measuring jar. In the present work, EGH . The volume of epoxy was maintained constant (40%) . The percentage volume of glass fabric is 30% and 30% volume of Hemp fabric is used in our work

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

Fig hand layup process

In the present work, Hand Lay-Up method of fabricating the composites was applied as the method is cheap, and can be comfortabilly made with available materials. Before giong to start lamination process, the required size and number of reinforcement layer is cut according to calculation. During this time the calculated quantity of epoxy and hardner are measured using a measuring jar and poured into a beaker. Soon after pouring hardner into Epoxy, the mixture is kept stirring, till the completion of lamination using a glass rod. But in the present work along with reinforced composites, were also fabracited. For fabricating the composite, the procedure is to follow by calculating the required quantity of epoxy and glass fabric layers and polyester fabrics layers, using the law of consistancy of volume. The measured quantity of epoxy is poured in a beaker, and then the hardner is added to the epoxy, and the mixture is stirred well . This mixture is used for lamination.

The volume of the each fabric and the matrix material is as shown in Table below

TYPES	Volume fraction in %		
	Epoxy resin	Glass fabric	Hemp fabric
EGH	40	30	30

4. RESULTS AND DISCUSSION

The experimentation have been carried out to characterize the composite material under loading condition on glass/Hemp polymer hybrid composite. The analysis of the result and the influence of various parameters on the Tensile, compression and joints (adhesive and bolted) are summarized in the following section

4.1 EFFECT OF TENSILE LOAD ON THE EGH HYBRID COMPOSITE

Tensile test were conducted on glass and Hemp fabric under tensile loading and the obtained result are plotted in the graph below.

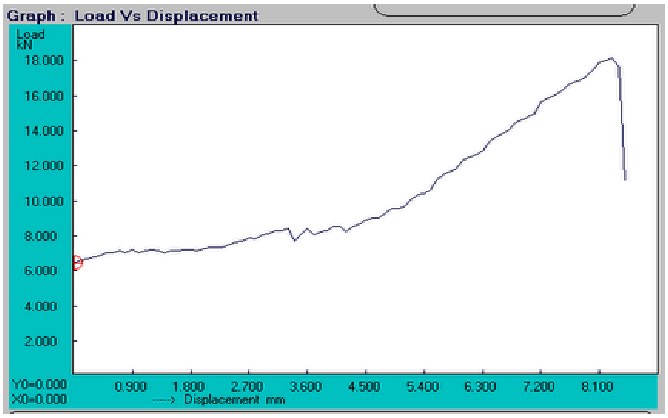

Fig 4.1 Load versus displacement curve for tensile strength

Fig 4.1a Before testing

Fig 4.1b After testing

Fig4.1 shows that load versus displacement on glass fabric and Hemp fabric. From graph it can be observed that deformation starts from the 6.5 KN and as the load increases deformation also increases. If the volume of glass fabric increases the load carrying capacity also increases .This is because of high tensile modulus of glass and as Hemp increases, the deformation before failure as increased due to stretchable property. This is because of equi-proportion of glass and Hemp where as the glass acts as load carrying capacity and Hemp absorb the deformation. As observed from Fig 4.1a and Fig 4.1b in the before and after testing of specimen .the delamination is very less and fiber pull out is also less comparatively. This shows good adhesion of Hemp to glass and epoxy.

As for the result and graph the maximum load carrying capacity of the tested specimen is 18.12 KN and the maximum displacement is 8.6 mm and the specimen breaks at a load of 11.12 KN (breaking load).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

4.2 STRESSES AND STRAINS IN EGH HYBRID COMPOSITE UNDER TENSILE LOADING

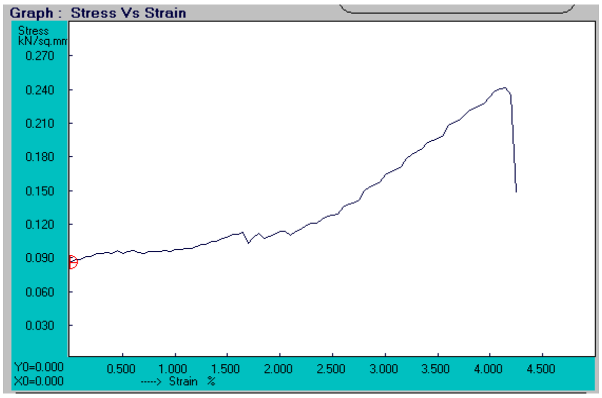

Fig 4.2 Graph showing stress vs strain of tensile

Fig 4.2 shows stress versus strain. From graph it can be observed that the strain increases from 0.090 KN/mm^2 of stress because of specimen is in plastic limit, so we can say that elastic range starts from 0.090 KN/mm^2, due to increase in stress the strain also increases, as the stress continues and it reaches the maximum stress of 0.242 KN/mm^2 ,further the stress decreases suddenly.

From the graph we observed that the ultimate stress obtained as 0.242 KN/mm^2 and the maximum strain is 4.3 %

4.3 EFFECT OF COMPRESSION LOAD ON THE EGH HYBRID COMPOSITE

Compression test were conducted on glass and Hemp fabric under compression loading and the obtained result are plotted in the graph below.

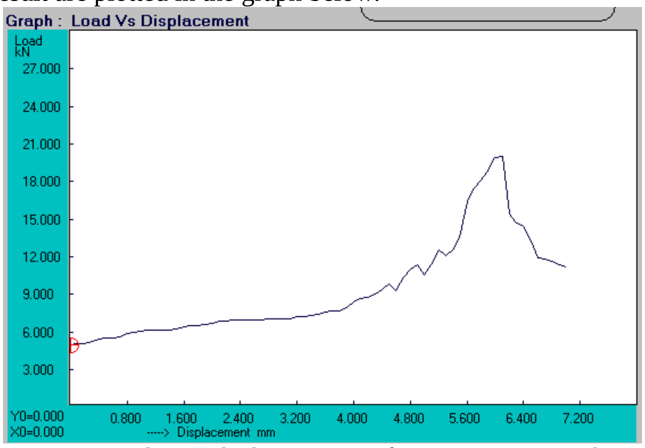

Fig 4.3 Load versus displacement curve for compression strength

Fig 4.3a Before testing

Fig 4.3b After testing

Fig 4.3 shows the above graph gives load versus displacement on glass fabric and Hemp fabric. From graph it can be observed that deformation starts from the 5 KN and as the load increases deformation also increases. If the volume of glass fabric increases the load carrying capacity also increases .This is because of high compression modulus of glass and as Hemp increases, the deformation before failure as increased due to stretchable property. This is because of equi-proportion of glass and Hemp where as the glass acts as load carrying capacity and Hemp absorb the deformation. As observed from Fig 4.3a and Fig 4.3b the before and after testing of specimen the delamination is very less and fiber pull out is also less comparatively. This shows good adhesion of Hemp to glass and epoxy.

As for the result and graph the maximum lode carrying capacity of the tested specimen is 20.04 KN and the maximum displacement is 7.1 mm and the specimen breaks at a load of 11.220 KN (braking load).

*4.4 STRESSES AND STRAINS IN EGH HYBRID COMPOSITE UNDER COMPRESSION LOAD***ING**

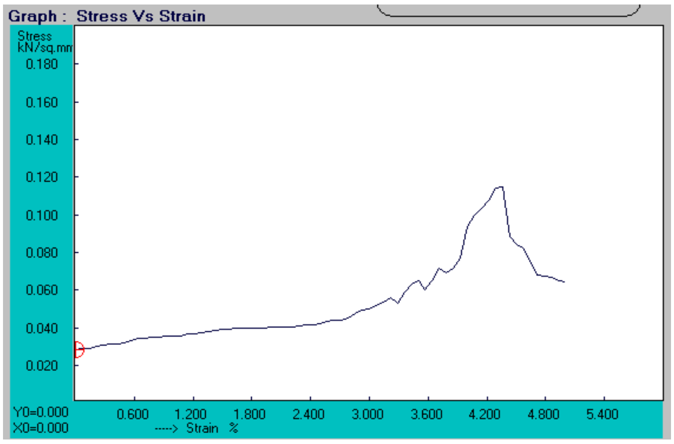

Fig 4.4 Graph showing stress vs strain of compression

Fig 4.4 shows stress versus strain. From graph it can be observed that the strain increases from 0.030 KN/mm^2 of stress because of specimen is in plastic limit, so we can say that elastic range starts from 0.030 KN/mm^2, due to increase in stress the strain also increases, as the stress continues and it reaches the maximum stress of 0.115 KN/mm^2 , further the stress decreases suddenly.

From the graph we observed that the ultimate stress obtained as 0.115 KN/mm^2 and the maximum strain is 4.95 **%.**

4.5 Effect of Bolted Fastening For Bolted- Lap Joint On Egs Hybrid Composite Under Tensile Loading

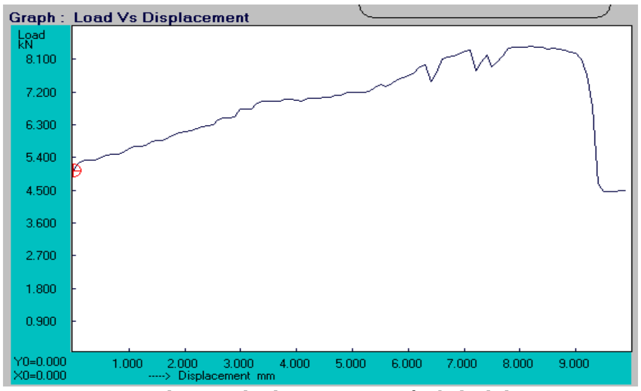

Fig 4.5 Load versus displacement curve for bolted- lap joint

Fig 4.5a Before testing

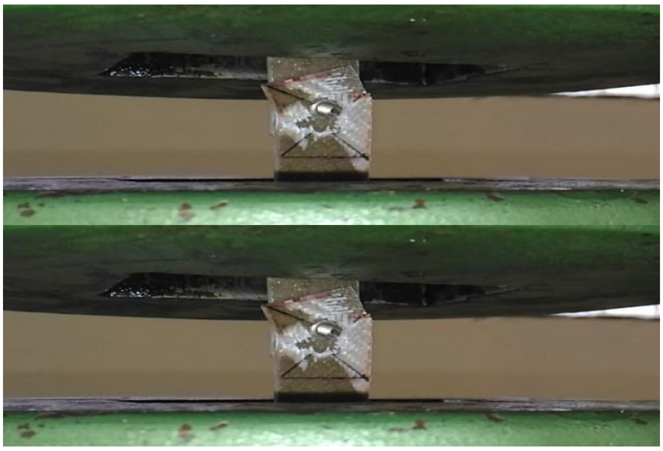

Fig 4.5b After testing

Fig shows the load versus displacement for bolted lap joint for volume fraction of glass fabric and Hemp fabric. From graph it can be observed that deformation starts from the 5.1 KN and as the load increases deformation also increases.

From the fig 4.5a and fig 4.5b ,it can be concluded that the specimen with bolt configuration failed under irreversible damage that is delamination and through thickness shear cracking. While the final load drops is associate with the fastener head pulling through the laminate. The front face of the specimen showed no visible damage with the exception that the fastener hole being enlarged to the head size. The back face showed material membrane failure and extensive delamination of the underlying plies and to determine that failure was a result of diagonal shear cracking and delamination.

As for the result and graph the maximum lode carrying capacity of the tested specimen is 8.46 KN and the maximum displacement is 9.9 mm and the specimen breaks at a load of 4.480 KN (breaking load).

4.6 Stresses And Strains In Egh Hybrid Composite Under Bolted Lap Joint Tensile Loading

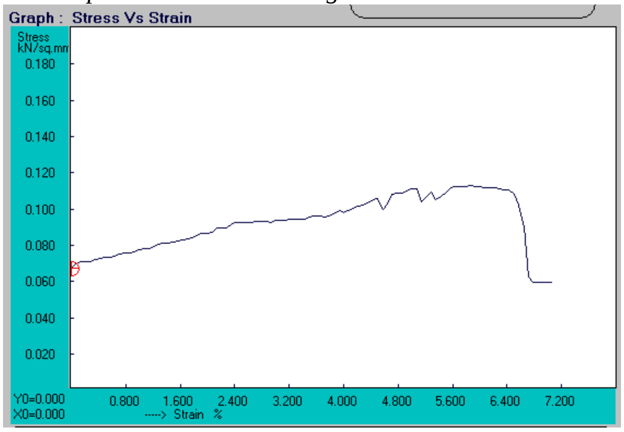

Fig 4.6 Graph showing stress vs strain of bolted lap joint

Fig4.6 shows stress versus strain. From graph it can be observed that the strain increases from 0.070 KN/mm^2 of stress because of specimen is in plastic limit, so we can say that elastic range starts from 0.070 KN/mm^2, due to increase in stress the strain also increases, as the stress continues and it reaches the maximum stress of 0.113 KN/mm^2 ,further the stress decreases suddenly. From the graph we observed that the ultimate stress obtained as 0.113 KN/mm^2 and the maximum strain is 7.07 %

4.7 Effect of Bolted Fastening For Bolted- Lap Joint On Egs Hybrid Composite Under Compression Loading

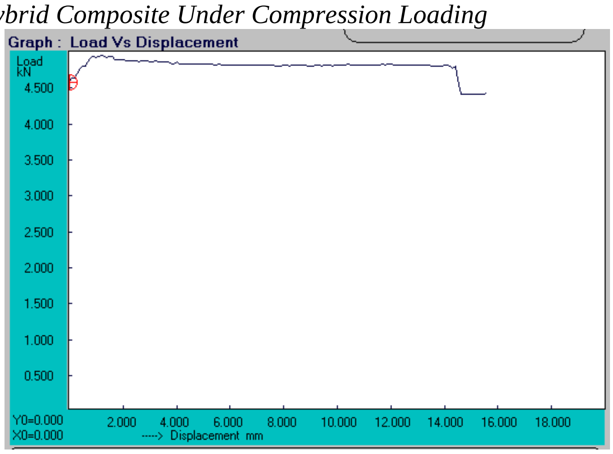

Fig 4.7 Load versus displacement curve for bolted- lap joint

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

Fig 4.7a Before testing

Fig 4.7b After testing

Fig 4.7 shows the load versus displacement for bolted lap joint for volume fraction of glass fabric and Hemp fabric. From graph it can be observed that deformation starts from the 4.5 KN and as the load increases deformation also increases.

From the fig 4.7a and fig4.7b ,it can be concluded that the specimen with bolt configuration failed under irreversible damage that is delamination and through thickness shear cracking. While the final load drops is associate with the fastener head compressing through the laminate. The front face of the specimen showed no visible damage with the exception that the fastener hole being enlarged to the head size. The back face showed material membrane failure and extensive elimination of the underlying plies and to determine that failure was a result of diagonal shear cracking and delimitation.

As for the result and graph the maximum lode carrying capacity of the tested specimen is 4.96 KN and the maximum displacement is 15.6 mm and the specimen breaks at a load of 4.44 KN (braking load).

4.8 STRESSES AND STRAINS IN EGH HYBRID COMPOSITE UNDER BOLTED LAP JOINT COMPRESSION LOADING

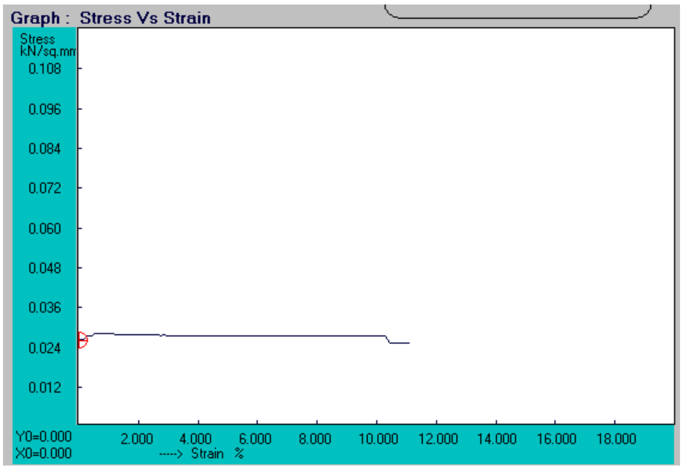

Fig 4.8 Graph showing stress vs strain of bolted lap joint

Fig shows stress versus strain. From graph it can be observed that the strain increases from 0.024 KN/mm^2 of stress because of specimen is in plastic limit, so we can say that elastic range starts from 0.024 KN/mm^2, due to increase in stress the strain also increases, as the stress continues and it reaches the maximum stress of 0.028 KN/mm^2 ,further the stress decreases suddenly. From the graph we observed that the ultimate stress obtained as 0.028 KN/mm^2 and the maximum strain is 11.6 %

4.9 EFFECT OF ADHESIVE BONDING FOR ADHESIVE-LAP JOINT ON EGH HYBRID COMPOSITE UNDER TENSILE LOADING

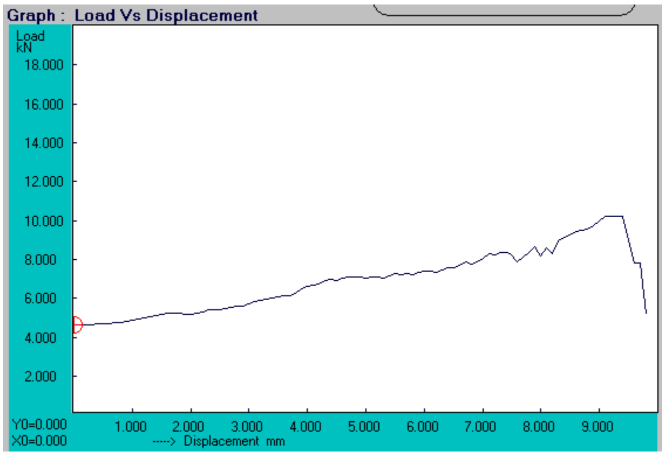

Fig 4.9 Load versus displacement curve of adhesive- lap joint

Fig 4.9 shows the load versus displacement of adhesive lap joint for volume fraction of glass fabric and Hemp fabric. From graph it can be observed that deformation starts from the 4.8 kN and as the load increases deformation also increases.

International Journal of Engineering Research & Technology (IJERT)
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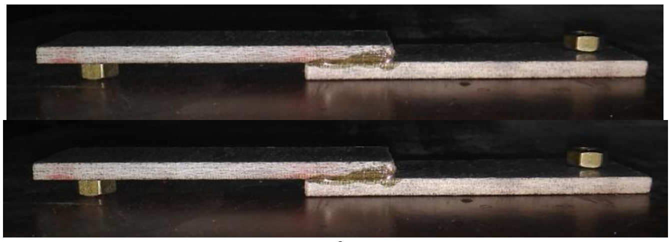

Fig 4.9a Before testing

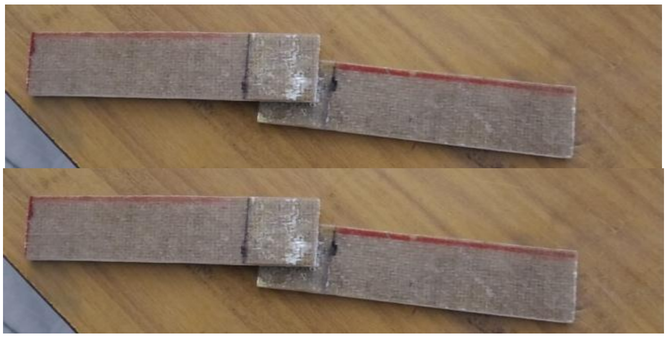

Fig 4.9b After testing

Fig4.9a and fig 4.9b shows the before and after testing of specimen for adhesive lap joint. In the EGH show an interfacial failure and also sometimes referred to as adhesive failure. In this failure rupture of the adhesively bonded joint, such that the separation appears to be at the adhesive adherend interface. In this category of specimen failure observation is wholly different from those of the others because it fails as a result of pure deboning between the composite laminate and the adhesive. This indicates that the bonding force of the adhesive become weaker in the EGH joint . As for the result and graph the maximum lode carrying capacity of the tested specimen is 10.240 KN and the maximum displacement is 9.8 mm and the specimen breaks at a load of 5.160 KN (breaking load).

4.10 STRESSES AND STRAINS IN EGH HYBRID COMPOSITE UNDER ADHESIVE LAP JOINT TENSILE LOADING

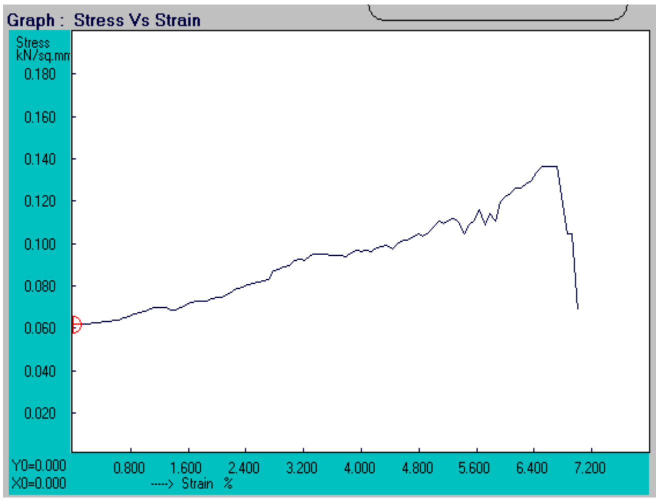

Fig 4.10 Graph showing stress vs strain of adhesive lap joint

Fig 4.10 shows stress versus strain. From graph it can be observed that the strain increases from 0.060 KN/mm^2 of stress because of specimen is in plastic limit, so we can say that elastic range starts from 0.060 KN/mm^2, due to increase in stress the strain also increases, as the stress continues and it reaches the maximum stress of 0.137 KN/mm^2 ,further the stress decreases suddenly. From the graph we observed that the ultimate stress obtained as 0.137 KN/mm^2 and the maximum strain is 7.00 %

4.11 EFFECT OF ADHESIVE BONDING FOR ADHESIVE- LAP JOINT ON EGH HYBRID COMPOSITE UNDER COMPRESSION LOADING

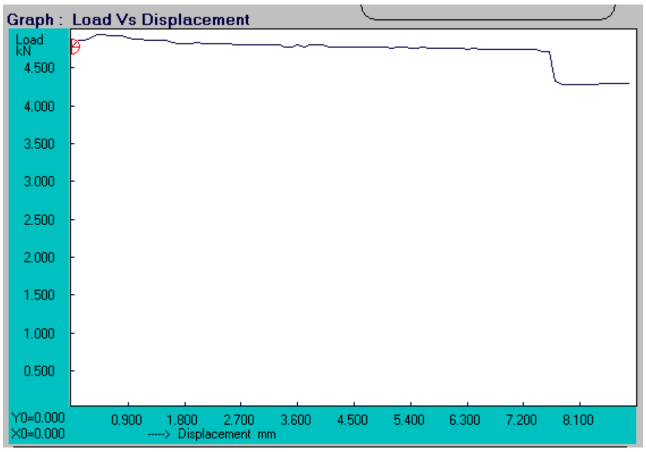

Fig 4.11 Load versus displacement curve of adhesive- lap joint

Fig4.11 shows the load versus displacement of adhesive lap joint for volume fraction of glass fabric and Hemp fabric. From graph it can be observed that deformation starts from the 4.94 KN and as the load increases deformation also increases.

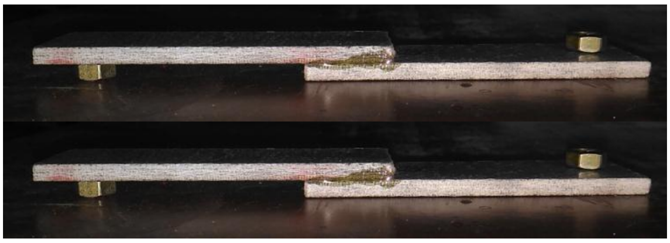

Fig 4.11a Before testing

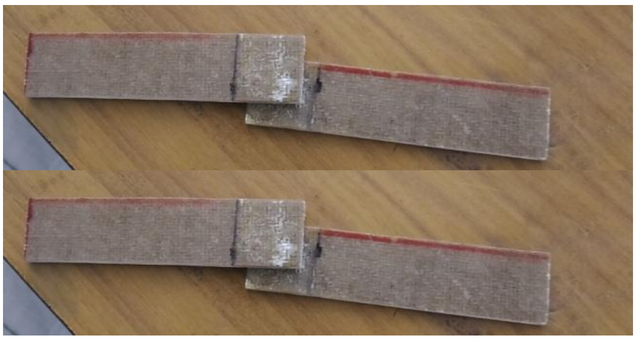

Fig 4.11b After testing

Fig 4.11a and fig 4.11b shows the before and after testing of specimen for adhesive lap joint. In the EGH show an interfacial failure and also sometimes referred to as adhesive failure. In this failure rupture of the adhesively bonded joint, such that the separation appears to be at the adhesive adherend interface. In this category of specimen failure observation is wholly different from those of the others because it fails as a result of pure deboning between the composite laminate and the adhesive. This indicates that the bonding force of the adhesive become weaker in the EGH joint . As for the result and graph the maximum lode carrying capacity of the tested specimen is 4.94 KN and the maximum displacement is 8.9 mm and the specimen breaks at a load of 4.3 KN (braking load).

4.12 STRESSES AND STRAINS IN EGH HYBRID COMPOSITE UNDER ADHESIVE LAP JOINT COMPRESSION LOADING

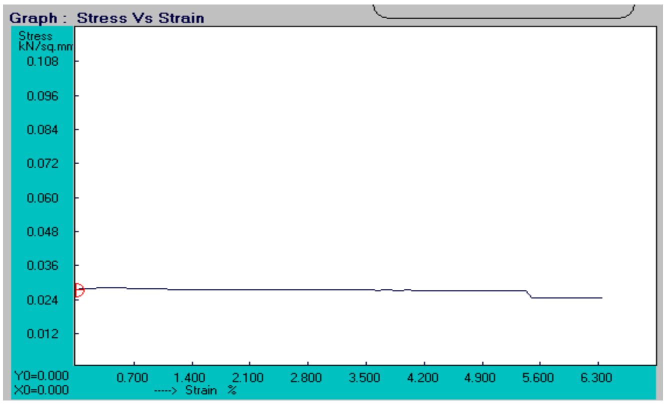

Fig 4.12 Graph showing stress vs strain of adhesive lap joint

Fig 4.12 shows stress versus strain. From graph it can be observed that the strain increases from 0.0260 KN/mm^2 of stress because of specimen is in plastic limit, so we can say that elastic range starts from 0.0260 KN/mm^2, due to increase in stress the strain also increases, as the stress continues and it reaches the maximum stress of 0.028 KN/mm^2 ,further the stress decreases suddenly.

From the graph we observed that the ultimate stress obtained as 0.028 KN/mm^2 and the maximum strain is 6.32 %

5. CONCLUSION

The experimental investigations used for the analysis of tensile strength ,compression strength and strength of various types of joints such as lap adhesive joints, lap bolted joints behaviors of EGH hybrid composite laminate leads to the following conclusions,

- As the volume of glass fabrics increases in the composite, the load carrying capacity increases and as the volume of the hemp fabrics increases, hemp absorbs the deformation and expands few more elastic properties.
- EGH shows significantly good result in case of tensile test
- In case of lap bolted joint configuration is not much significant in compression test.
- In case of adhesive tensile and adhesive compression, the adhesive tensile shows good results

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