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Effect of Tensile Load on Repaired Composite Laminates

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***Abstract*:**

In this project is to study the tensile strength of the composite laminates subjected into low velocity impact damage. An experimental study was conducted to study the strength of various repair techniques on Glass Fiber Reinforced Plastics (GFRP). For evaluating tensile strength of the composite laminates ASTM D3039 standard tensile test specimens made using bi-directional glass fiber and epoxy resin. The size of the testing specimen is 250*25*4.5 mm. Then the specimens were impacted at low velocity impact energy to produce a limited and visible amount of damage. When applying impact energy to the specimens were going to produce deformations such as matrix cracking, fiber breaking and delamination's. The damages were inspected using Ultrasonic A-scan technique. The depths of the impact damage applied in the specimens were calculated and the damaged regions were removed subsequently and repaired using Bonded repair, Bolted repair and Hybrid repair techniques. The repaired specimens were subjected to tensile loading until failure occur using INSTRON Universal Testing Machine. The tensile strength of the original specimen, impact damaged specimen, repaired specimens (Bonded, Bolted and Hybrid) were calculated and also the results were compared. It gives the effect of tensile load on the original specimen, impacted specimen and repaired specimen.

Keywords—*composite laminates, impact damage, repair effect, tensile strength.*

I INTRODUCTION

The use of fiber reinforced composites has been increasing in industry, specially the aeronautical industry, because of its excellent characteristics of specific strength and stiffness. They present, however, high susceptibility to low velocity impact damage, which can occur during the life of any kind of composite structure. The accidental strikes by a tool or a bird in an airplane wings are examples of these events. It is then important to be able to detect the defects and to take the proper repairing actions once they can substantially reduce the residual strength. Moreover, due to recycling difficulties, it is more ecologically efficient to repair the structures instead of replacing them. The repair of composite structures with composite patches may use several techniques, such as mechanical fastening or adhesive bonding. Mechanical fastening often introduces stress concentrations in the contact area between the fastener and the composite, limiting the residual strength of the repaired plate. Adhesive bonding is one of most common repair techniques carried out in composite structures, either in the condition of temporary repair or permanent repair. As a temporary repair, it has the advantage of its easy application process especially when it is an external bonded repair. The repair procedure for this method is as follows: the damaged area is removed on the plate, and the removed area is cleaned and a same dimension patch is applied. This kind of repair is temporary method.

Another type of repair method is bolted repair; this may be used as a temporary repair method. Repair procedure for this method as follows: remove the damaged area and put holes for using bolt. Then create same dimension patch of removed area and put same holes already placed in the composite plate. Then place the patch on the damage removed area and using bolt fixed the patch and the plate together tightly. More efficient repair method is hybrid repair. In this method boded repair and bolted repair together to increase the strength of the repaired material. At first bonded repair method applied and then to increase its strength put holes and fixed with bolt. This will be a permanent repair method.

II SPECEIMEN PREPARATION

Bi-directional GFRP laminate of (600*300*4.5) mm was fabricated by hand lay-up method. 9 layers of bi-directional glass fiber (0-90) embedded with epoxy resin (LY556) and hardener (HY951) is used in the fabrication.

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ASTM D3039 standard sized test specimens (250*25*4.5) mm were cut from the fabricated laminates using water jet cutting to avoid machining defects and to maintain a smooth surface finish shown in fig.1 . Two taps were used on each side of the specimen (50*25*1.5) mm to facilitate breakage as close as possible to the Centre of the 100mm grip length and to reduce the grip noise shown in fig 3. Five types of specimen were prepared, four specimens in each category. 1. Original specimen, 2. Impacted specimen, 3. Bonded repaired specimens, 4. Bolted repaired specimen, 5. Hybrid repaired specimens.

Fig. 1 ASTM D3039 Standard Specimens

III IMPACT TESTING

ASTM D3039 standard specimens were subjected to impact loading using Low velocity Impact Testing Machine. For the low velocity impact test the intender is set to impact the specimen from a height of 0.23m which is determined by trial and error method. The specimen is kept in the specimen holder which holds the specimen firmly. A 16mm semi-hemispherical indenter with a mass of 5.2Kg is used. The energy absorbed is 1.121J. The intender impacts the specimen which is held by the holder which provides the time, energy, deformation, force data's through the Data Acquisition Systems. Impact damage mostly causes matrix cracking and delamination in laminates.

Fig. 2 Impact Testing

IV REPAIR OF IMPACT DAMAGES

Impacted specimens are selected to suitable repair methods, such as bonded, bolted and hybrid repair methods. Bonded repair method done for four specimens, bolted repair method done for four specimens and hybrid repair method done for four specimens. For bolted and hybrid repair method we used strut type metal bolts having half thread, because it will not damage the laminates when bolted and hybrid repair method done on the composite laminates.

Fig. 3 Testing Specimens

IV TENSILE TESTING

The specimens are selected and subjected to Uni-axial tension in a 30Kn INSTRON Universal Testing Machine Four specimen per each category (as received original, impacted, bonded repaired, bolted repaired and hybrid repaired specimens) were selected to tensile test.

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Fig. 4 Tensile Testing

V. RESULT AND DISCUSSION

The original strength of the specimens were tested in UTM at a rate of 5mm/min. The load at which the material failed was found to be an average of 17KN.

Fig.5 Tensile Test Of The Specimen.

The specimens were impacted and then their strengths were tested using UTM machine. The effect of impact can be measured in an average loss of tensile strength exceeding 36.84%. The scattering of values also increases after impact due to the variability of the extent of damage produced in the laminates by impact with the same energy that shows in fig. 5

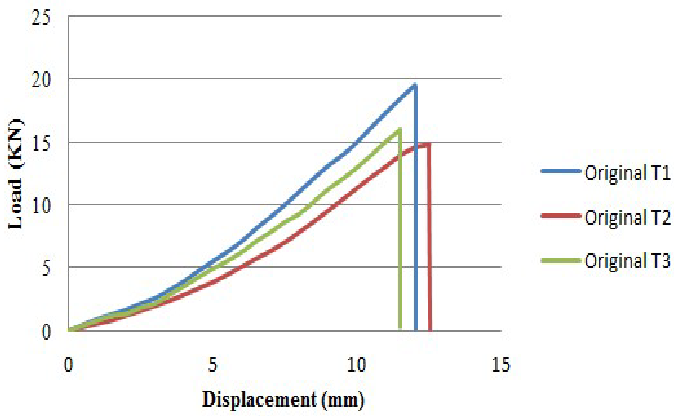

Fig.6 Graphs of Original Tensile Strength Of The Specimens.

Graph shows the original strength of the GFRP laminate specimens which can with stand maximum load in average 19.8KN and maximum displacement of the original specimen is 12.5mm.and also tensile test were carried out all repaired specimen also it shows the variable of reduction in strength and load carrying capacity. Tests were carried out and results were found and graphed.

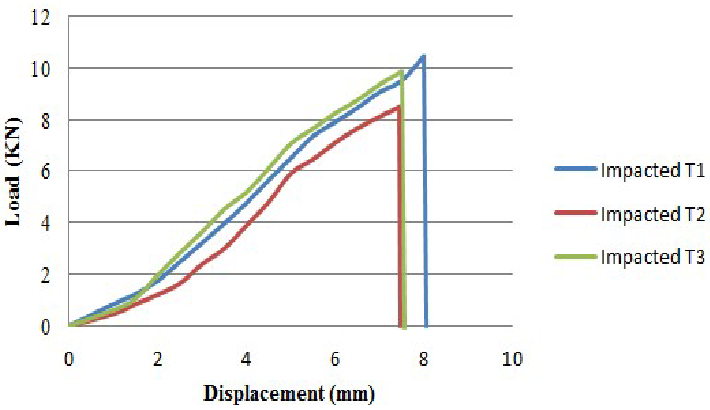

Fig.7 Graphs of Load Vs Displacement Impacted Specimen.

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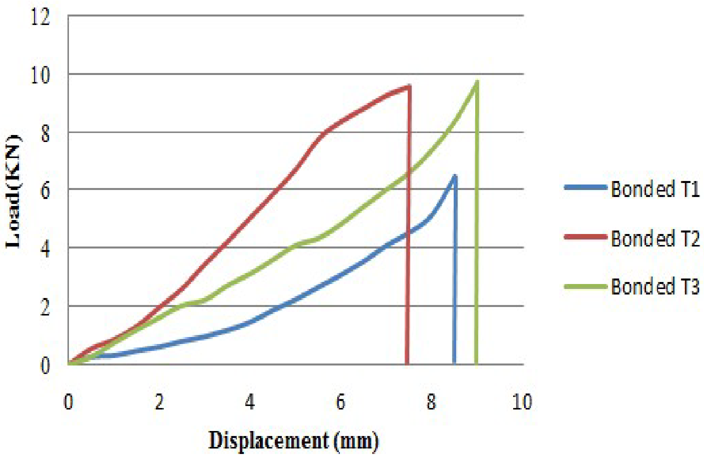

Fig.8 Graphs OF Load Vs Displacement Bonded Repaired Specimens.

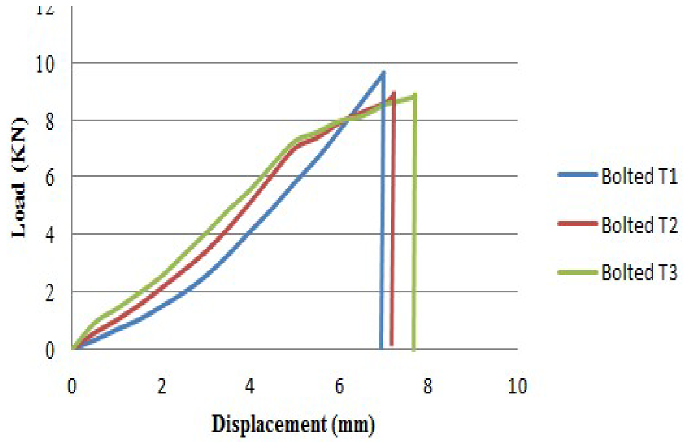

Fig.9 Graphs Of Load Vs Displacement Bolted Repaired Specimens.

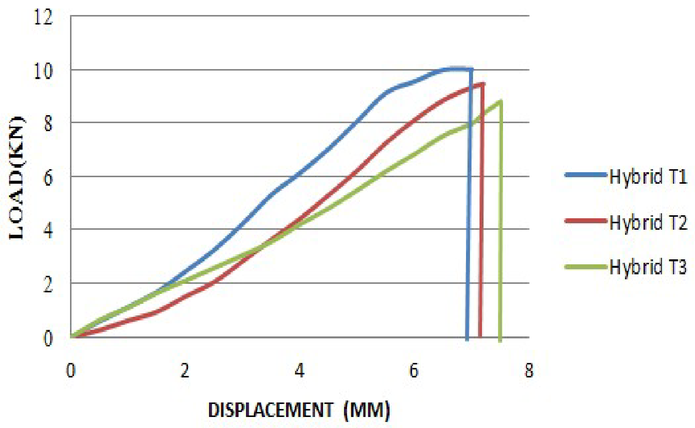

Fig.10 Graphs Of Load Vs Displacement Hybrid Repaired Specimens.

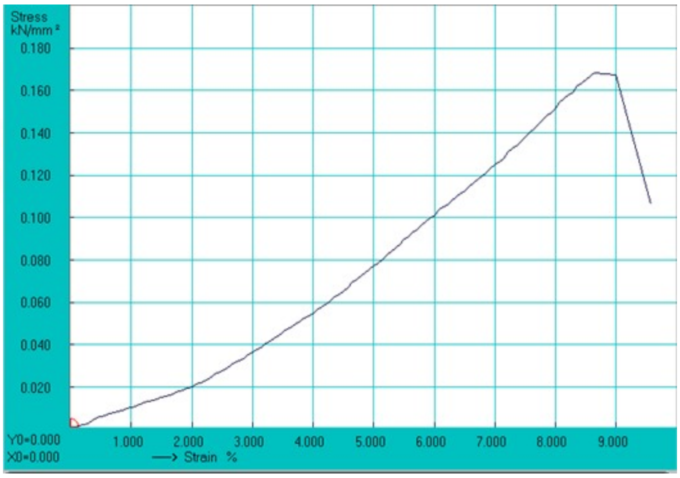

Fig.11 Stress Strain Ratio Of Original specimen.

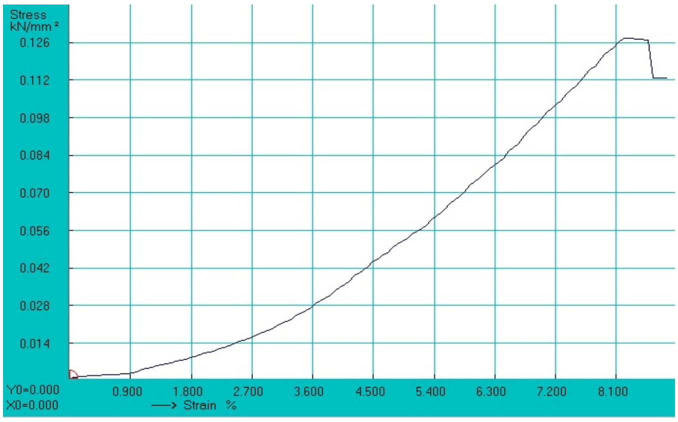

Fig.12 Stress Strain Ratio Of Impacted specimen.

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SPECIMEN	ELONGATION dl (mm)	MAX. LOAD (N)	EFFECT OF TENSILE LOAD
ORIGINAL	14.03	18,932	FIBER BREAKING
IMPACTED	7.5	13,105	FIBER DELAMINATION
BONDED REPAIR	10.8	16,782	PATCH DEBONDING
BOLTED REPAIR	8.4	13,125	CRACK IN THE HOLE
HYBRID REPAIR	10.4	14,958	CRACK IN THE HOLE

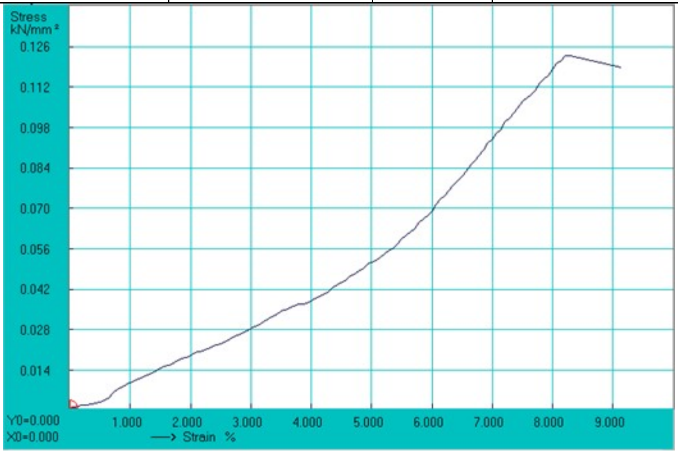

Fig.13 Stress Strain Ratio Of Bonded Repaired specimen.

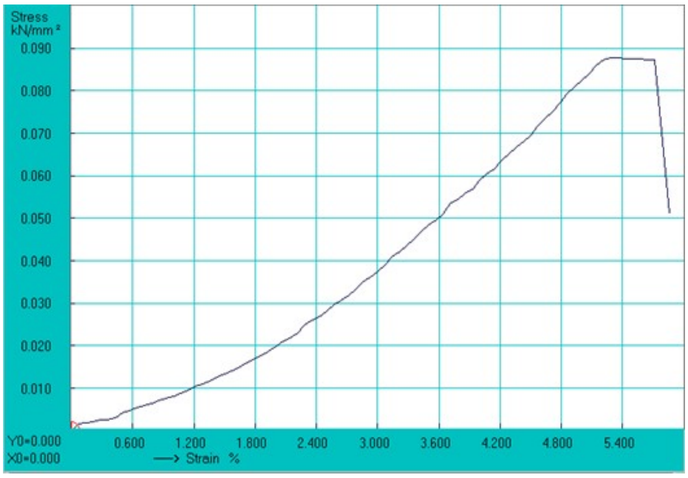

Fig.14 Stress Strain Ratio Of Bolted specimen.

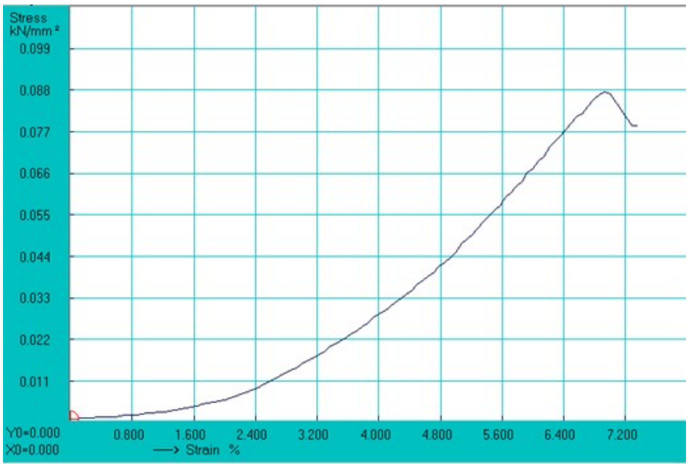

Fig.15 Stress Strain Ratio Of Hybrid Repaired specimen.

Table.1 Comparison Of Tensile Load Effect.

VI CONCLUSION

This paper discusses the main role of composite repair methodology and the effects of tensile load. It concludes that the repair method is to restore the structural strength of the damaged specimen. The conclusions made us follows, the method of bolted repair technique results in failure of crack made in the hole, strength of the specimen decrease due to the hole that put for bolted repair. More limited concentration of damage during tensile loading, but the specimen can't withstand the particular load. At the same time bonded repair method can withstand more load than the bolted repair method, so load carrying capacity is more than the bolted repair method. In the bonded repair method failure occurs due to debonding in the repaired area. Hybrid repair method is also carrying more load compare to bolted repair method, but in case of using bolt we put a hole in the specimen, so the strength of the specimen decrease gradually because of the hole, Maximum crack development is produced near to the holes only. Maximum tensile effect is created in the method of bolted repair, and also hybrid repair. In these three cases we used patches have been applied including resin and fibers in a volume of comparable with that of a bulk of a laminate. The results are given in the table. From the table we conclude that bolted and hybrid repair methods failure due to crack development in the holes. Failure occurred in the bonded repair method is due to debonding of patch in the repaired area.

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