An Investigation On Strength Deterioration Of Gfrp Composite Laminates Through Exposure Tests

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ABSTRACT

Fibre composites are being used in various applications from aerospace, military, marine boats and submarine to renewable energy generation. Higher energy demands across the developed and growing world for the usage and replacement of conventional materials with polymer composite materials for engineering applications which is always questioned by the end user, unless the research oriented reliable supporting certification is made available. The reinforcement materials are highly hygroscopic, the matrix material provides protection to the reinforcement. Since the edges of parts made of composite materials are exposed to environment, water molecules travels along the reinforcement and cause damage to the interfacial bonding, further the performance of the composite laminate gets effected. In this scenario, the investigation has been carried out for the strength deterioration of unpainted and painted GFRP composite laminates subjected to different environmental conditions. The experimental results showed that unpainted GFRP laminates showed a remarkable reduction in mechanical strength and retention ratio over period of 6months.Corresponding painted specimens showed small changes and also shows coating helps to prevent or minimize the changes in mechanical properties.

Keywords: GFRP (Glass fibre reinforced polymer), The Resin transfer moulding (RTM) , Environmental conditions, Tensile modulus retention ratio.

1. Introduction

Glass fiber reinforced composite materials are low cost, light-weight, better mechanical properties, free from health hazard, and thus have the potential for aircraft, automobile and similar structural applications. Carbon, Glass and Kelvar are the most commonly used composite materials in aerospace industry. The effects of moisture on retention of mechanical properties of glass fiber reinforced composites during long-term environmental exposure to moist conditions are very crucial for industrial applications. With reference to the work related to accelerated environmental ageing study of polyester/glass fibre reinforced composites [3], the results are indicating similar phenomena of delamination in the composite laminates. They studied dynamic mechanical analysis, for a range of temperatures and frequencies under tensile and three-point bending loadings, which revealed that the aged materials gained in stiffness; whereas a small deterioration in strength was found in our work accelerated environmental ageing is set up by constant temperature water bath. Tensile and flexural strength of bamboo fibre reinforced polypropylene composite and bamboo-glass fibre reinforced polypropylene hybrid composite were reduced [5]. On similar way experimental work has been done with polyester-glass fibre reinforced composites. The environmental stress cracking failure due to temperature and moisture has been studied for glass fibre reinforced composites [6]. Moisture does not only affect the adhesive bond of the bonded system in service, but also during the application of FRP on concrete surface. Tests on CFRP bonded to concrete with initially damp surface using a modified cantilever beam indicated reduction in bond strength when compared to specimens with initially dry concrete surface [7]. Since the failure under effect of moisture generally occurs by either concrete delamination or concrete–epoxy interface separation. The effects of variable moisture conditions on the fracture toughness of concrete/FRP bonded system are studied by means of the peel and shear fracture toughness determined from the conditioned test specimens. Moisture conditions can result in strength degradation [8].There have been some strength degradation and durability studies [9] based on moist ,salt and temperature exposure tests.

The objective of this work is to investigate experimentally the effects of hydrothermal aging environmental conditions on the performance and durability of unpainted and painted glass fibre reinforced polymer materials. For this number of specimens are prepared, some of specimens are exposed to accelerated hydrothermal environmental conditions and some of specimens are painted with resin and exposed to same conditions .To know the changes of material properties due to water absorption at room temperature and elevated temperature. For this series of experiments are conducted and results are interpreted to know behaviour of the materials. Also the relation between stress verses strain curves are prepared to evaluate tensile modulus of material.

2 EXPERIMENTAL SETUP

2.1 Production of laminates using RTM

The specimens for the present work are prepared using RTM Machine. The Resin transfer moulding (RTM) machine, a closed mould process, consists of resin injection equipment, it has a hollow cylinder fitted with pressure gauge, valve and pressure pump and mould plates as shown fig1.

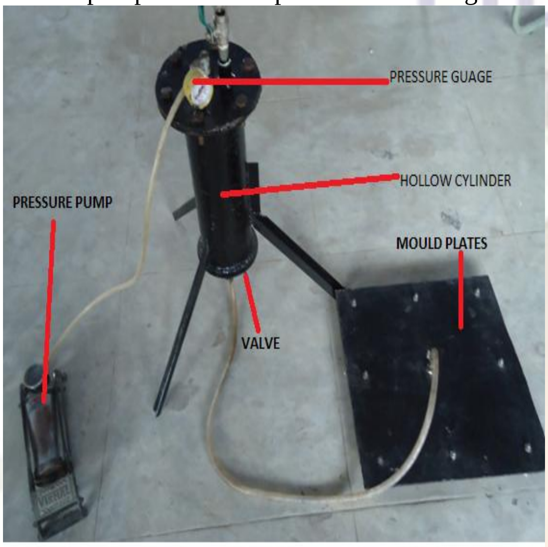


Fig. 1: RTM (Resin transfer molding)Machine

The materials used for GFRP laminates are polyester resin (commercial grade with density 1.35g/cm^3 manufactured by Ciba Geigy Ltd. and supplied by Northern polymers New Delhi India) and Glass fibre mats (E-glass woven fabric glass fibre with density 450g/cm^2 manufactured by Saint Gobian Ltd .India) with composition of 60%matrix (polyester resin) and 40% of glass fibre. The specifications for the laminate preparation are (i)injection pressures, 30-40 psi. (ii) Curing Temperature – room temperature. The glass fibre mats are placed between the mould plates and clamped before sending the resin. The chemically combined resin that is resin mixed with 2% of accelerator (cobalt nathylene) and 2%of catalyst (methyl ethyl keypricperoxide) is poured inside the hollow cylinder through the valve present at top cap and immediately the valve is closed and the air is pumped into hollow cylinder up to maximum pressure of 40Psi. The bottom valve of the cylinder is slowly released so that pressurized chemical resin enters in to the mould and it is spread equally in to all directions. To get a well-shaped laminate allow the mould to be idle for 4 to 5 hours and laminate is solidified then unseal the mould separate the lower and upper mould parts . The laminate is slightly sticky to the mould surface and removed forcibly and laminate of mould shape is as shown fig.2.

Specimen preparation: The laminate obtained is difficult to test, and to have tensile test for that laminates are sliced to standard ASTMD638 specimen of dimensions 250 mm X 30 mm X 8mm mm (as shown fig.3) by using the circular saw machine. Number of the unpainted specimens and painted specimens are prepared. The painted specimens are prepared by coating the surfaces and edges with polyester resin.

Fig. 2: composite laminate piece

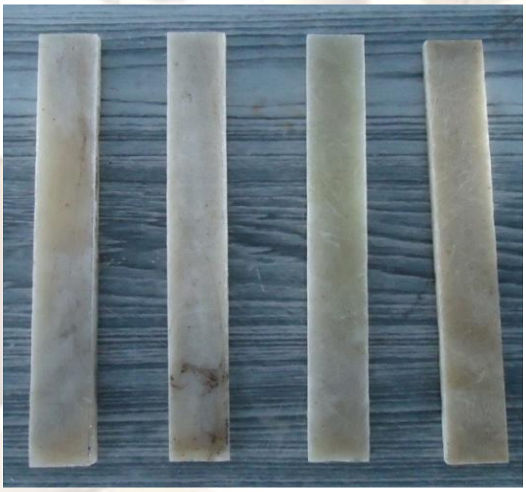


Fig.3. Test specimens produced from laminate

2.2 Testing of the Laminates

The laminates obtained by RTM process are 300mm X 300mm X 8mm as shown in the fig. 2. From that standard specimen of dimensions 250mm X 30mm X 8mm are prepared,(as shown in fig.3) . Some of the unpainted and painted specimens thus prepared are exposed in water at room temperature for 180days and some of them (unpainted & painted) are exposed to constant temperature (60^{0}C) in water bath tub (as shown in fig.4) for period of 60days and some of them in salt bath tub at same constant temperature and exposure time. At every 30 days few specimens are taken from water bath at room temperature and at every 10 days few specimens are taken from constant temperature water bath tub and salt bath tub for mechanical testing. Tensile properties are evaluated by conducting tensile test on UTM as shown fig.6. Stress-strain curve are drawn from the test results and calculated the tensile modulus.

Fig.4 Constant temperature water bath

Fig.5.Constant temperature water bath with specimens

Fig.6 Tensile testing on UTM

3.0 RESULTS AND DISCUSSIONS

3.1 RESULTS OF TENSILE TEST:

Specimen size: Specimen Length=250 mm, Specimen Gauge Length=200 mm, Width b=30 mm, Thickness h=8 mm.

3.1.1 Tensile test-Unpainted Specimens exposed in water at room temperature:

The number of specimens of dimensions 250mm X30mm X 8mm are exposed to water bath at room temperature, and same tested with tensile test. This is repeated for every 30days and the results are noted and the same plotted in graph 1.From the graph tensile modulus calculated and shown in table.1

3.1.2 Tensile test-Painted Specimens exposed in water at room temperature:

The number of specimens of dimensions 250mm X30mm X 8mm are exposed to water bath at room temperature, and same tested with tensile test. This is repeated for every 30days and the results are noted and the same plotted in graph 2. .From the graph tensile modulus calculated and shown in table.1

3.2.1 Tensile test- Unpainted Specimens exposed in water at constant temperature 60^{0}C:

The number of specimens of dimensions 250mm X30mm X 8mm are exposed to water bath at constant temperature 60^{0}C, and same tested with tensile test. This is repeated for every 10days and the results are noted and the same plotted in graph 3. .From the graph tensile modulus calculated and shown in table.2

3.2.2 Tensile test- Painted Specimens exposed in water at constant temperature 60^{0}C:

The number of specimens of dimensions 250mm X30mm X 8mm are exposed to water bath at constant temperature 60^{0}C, and same tested with tensile test. This is repeated for every 10days and the results are noted and the same plotted in graph4.From the graph tensile modulus calculated and shown in table.2

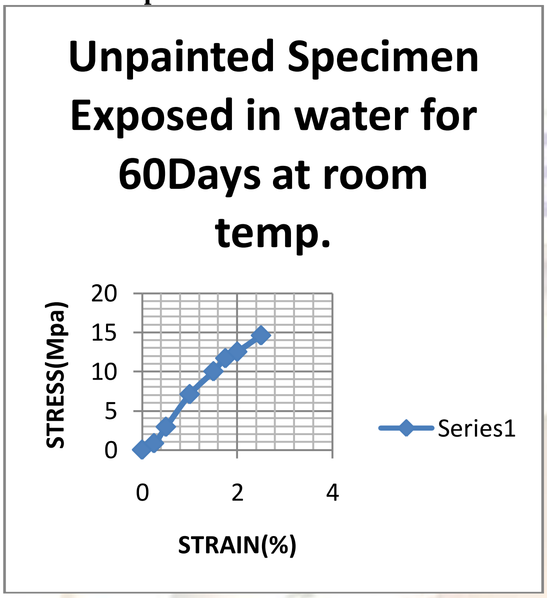
3.3.1 Tensile test- Unpainted Specimens exposed in salt water at constant temperature 60^{0}C:

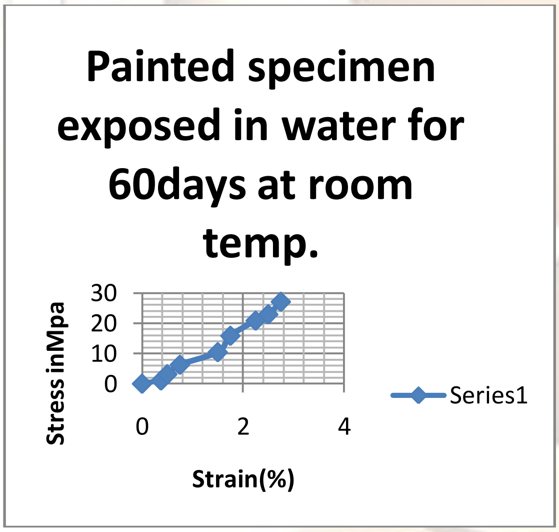
The numbers of specimens of dimensions 250mmX30mmX8mm are exposed to salt water bath at constant temperature 60^{0}C, and same tested with tensile test. This is repeated for every 10 days, the results are noted and the same displayed in graph 5. From the graph tensile modulus calculated and shown in table.2

3.3 .Model calculation for Tensile modulus

From stress-strain graphs tensile modulus of the specimens are calculated within the elastic limits choosing the three points in a straight line portion corresponding to 0.8, 1 &1.2 percentage of strain and tabulated in table1 for example unpainted and painted specimen exposed in water for 60 days the tensile modulus from the following graphs is calculated as Tensile modulus unpainted specimen (60 Days), $\mathbf{E_2}$ **= (5.8/0.8+7.08/1+8.2/1.2)/3*100 N/mm^2**

=0.711Gpa

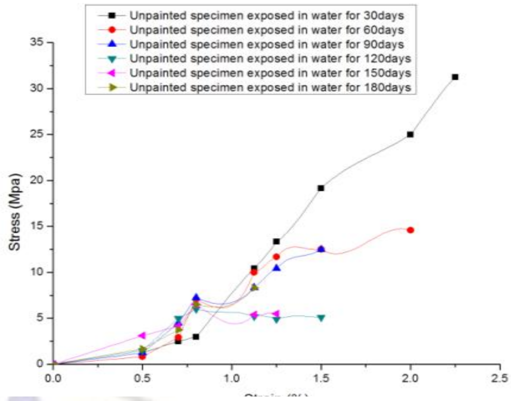




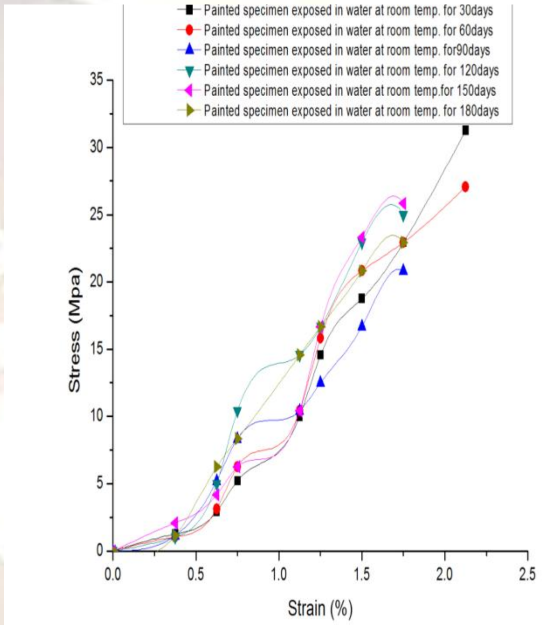
Tensile modulus painted specimen (60 Days), **E2 = (7.0/0.8+7.80/1+12/1.2)/3*100 N/mm^2**

=0.801Gpa

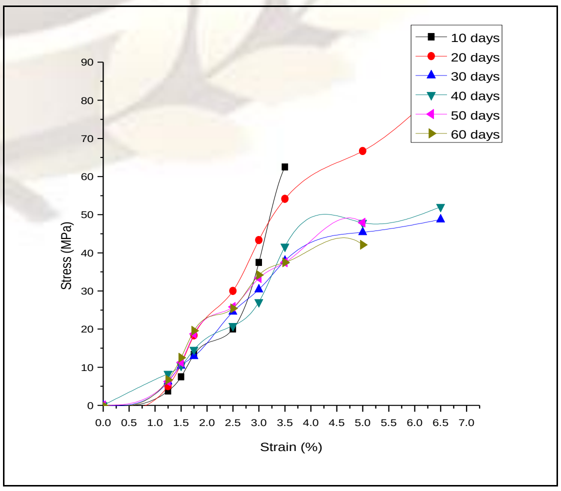
This calculation procedure applied for the test results of stress-strain graphs and tabulated in table1 and table2.



Graph.1: Tensile test -Stress-Strain for unpainted specimen exposed in water at room temperature (Specimen exposure time 30days to 180days)

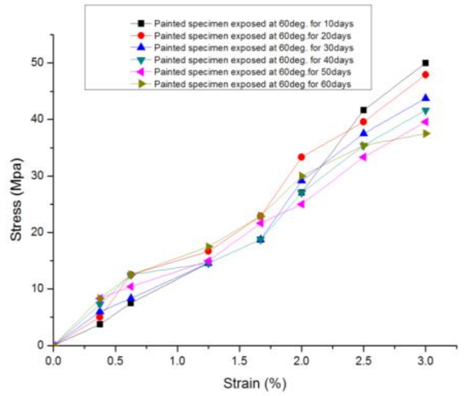


Graph 2: Tensile test -Stress-Strain for painted specimen exposed in water at room temperature (Specimen exposure time 30days to 180days)

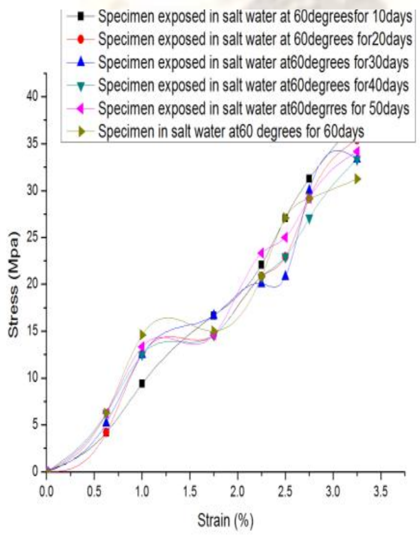


Graph.3: Tensile test -Stress-Strain unpainted

specimen exposed in water at constant temperature 60^0C(Specimen exposure time 10days to 60days)



Graph.4: Tensile test -Stress-Strain painted specimen exposed in water at constant temperature 60^0C(Specimen exposure time 10days to 60days)



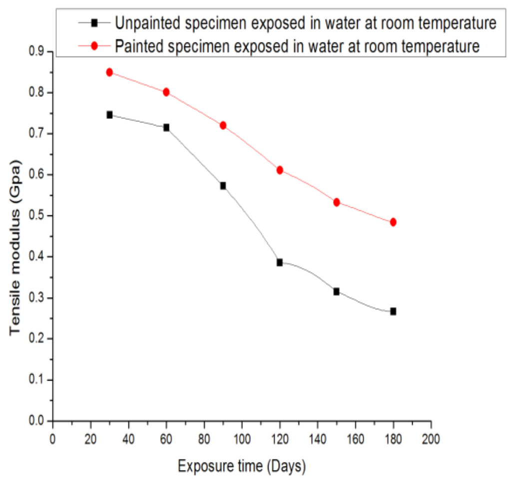
Graph.5: Tensile test -Stress-Strain unpainted specimen exposed in saltwater at constant temperature 60^0 C(Specimen exposure time 10days to 60days).

Table.1: Tensile modulus and Retention ratio of Specimen exposed in water at room temperature

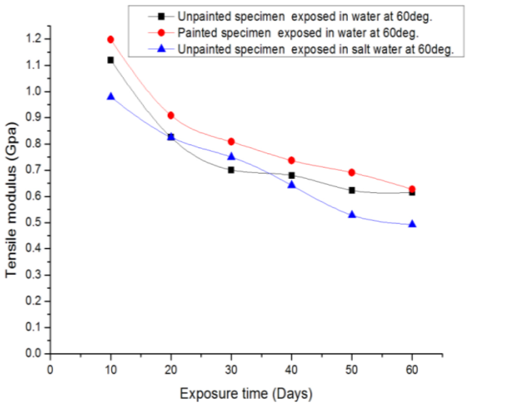
Specimens exposed in water at room Temp.				
Unexposed Specimen Tensile modulus=0.97Gpa				
	Unpainted specimen		painted specimen	
Exposure Time days	Tensile Modulus (Gpa)	Retention ratio	Tensile Modulus (Gpa)	Retention ratio
30	0.746	0.77	0.850	0.88
60	0.715	0.75	0.801	0.83
90	0.573	0.59	0.720	0.74
120	0.386	0.40	0.611	0.63
150	0.315	0.33	0.533	0.55
180	0.267	0.28	0.484	0.50

Table.2: Tensile modulus and Retention ratio of Specimen exposed in water and salt water at 60^0C Constant temperature.

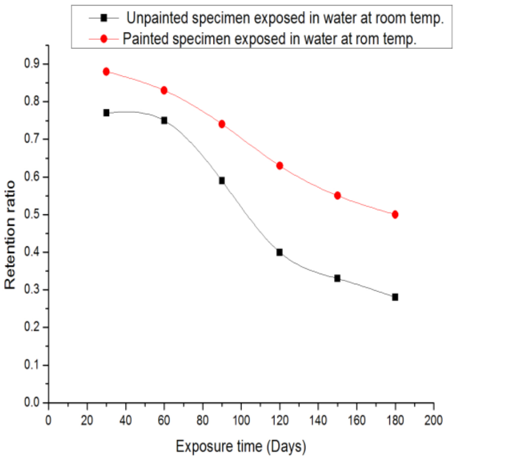
Unexposed Specimen Tensile modulus=0.97Gpa						
Specimens exposed at 60^0C constant Temperature						
in water					in salt water	
	Unpainted specimen		painted specimen		Unpainted specimen	
Exposure	Tensile Modulus (Gpa)	Retention ratio	Tensile Modulus (Gpa)	Retention ratio	Tensile Modulus (Gpa)	Retention ratio
10	1.120	1.15	1.198	1.23	0.979	1.01
20	0.825	0.85	0.909	0.94	0.825	0.85
30	0.701	0.72	0.808	0.83	0.75	0.77
40	0.68	0.70	0.737	0.76	0.642	0.66
50	0.623	0.64	0.690	0.71	0.528	0.54
60	0.615	0.63	0.627	0.65	0.492	0.51



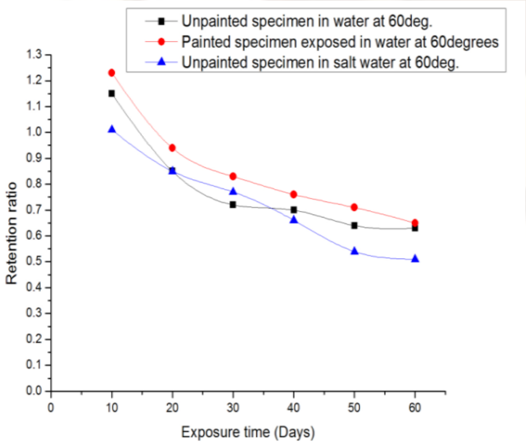
Graph 6: Tensile Stress V/S Exposure time for unpainted and painted specimen exposed in water at room temperature (Specimen exposure time 30days to 180days)



Graph7: Tensile Stress V/S Exposure time for unpainted and painted specimen exposed in water and salt water at 60^0C temperature (Specimen exposure time 10days to 60days).



Graph.8:Retention ratio V/S Exposure time for unpainted and painted specimen exposed in water at room temperature (Specimen exposure time 30days to 180days)



Graph9: Retention ratio V/S Exposure time for unpainted and painted specimen exposed in water and salt water at 60^0C temperature (Specimen exposure time 10days to 60days).

3.4: DISCUSSIONS

The experimental results revealed that the GFRP (E-Glass/Polyester)unpainted and painted samples were subjected to aging at room temperature in water for 180days and at 60^0C constant temperature in water and salt water for 60days results as shown in table 1 and table2.The painted samples has been prepared by resin coating on surface and edge of the specimens. As per the experimental results of unpainted and painted exposed in water at room temperature, the strength degradation (tensile modulus) is more in unpainted samples. The retention ratio (ratio of tensile modulus of exposed specimen to unexposed specimen) showed a steady decrease(less reduction) in the painted specimen comparing with unpainted specimen. As per the experimental results of unpainted and painted specimens exposed in water and salt water at constant temperature 60^0C, initially tensile strength appear to be increased as soaking(exposure) time is increasing this is because of cross linking reaction in polyester resin is still in progress up to 2 weeks of laminate preparation. The damage degradation water molecular sleep age is dominated by cross linkage speed. Hence there is nominal increment in the mechanical properties is appear. After that rapid reduction in mechanical properties is observed in unpainted specimens and gradual decrease is observed in painted specimens over the exposure time. The tensile modulus has a sharp reduction for the specimen exposed in water as compared to specimens exposed in salt water because of more moisture interference in fibre matrix in the water then salt water. The samples subjected to aging at the constant temperature water bath (60ºC) showed a hyperbolic decrement in the tensile strength. On the whole it was observed that less reduction of tensile modulus in painted specimens than unpainted specimens with the presence of moisture and temperature.

There is significant reduction in modulus because of loosing bonding strength of the polyester resin at temperature. It is clear that the tensile modulus rapidly decreases due to hydrothermal aging because moisture generally affects any property which is dominated by the matrix and/or interface.

The retention ratio (as shown in tables1.&2.) has been calculated for tensile modulus and it clear that gradual reduction over exposure time of 60days for painted and unpainted specimens as shown in Graphs.8&9.

4.0 CONCLUSIONS

The investigation showed a remarkable reduction in mechanical strength (tensile modulus) of unpainted and painted GFRP composite laminates which are subjected to different environmental conditions over exposed time. The tensile strength values of the unpainted specimens are rapidly decreases compare to painted specimens over exposure period of 180 days in water at room temperature and 60 days in water and salt water at constant temperature. As per the results the retention ratio was about 0.88 to 0.50 in case of painted specimens but in case of unpainted specimens it was 0.77 to 0.28.This results shows that strength deterioration of GFRP composite laminates subjected to exposure tests. The following points drawn from test results in this study.

a). The Composite material moisture absorption is more. The presence of moisture or water particles in the matrix, fibre-matrix interface and also attack on the glass fibres are all the reason for reduction of properties due to environmental impact.

b) In this investigation different environmental conditions were used with painted and unpainted specimens in testing, the painted specimens showed small changes in some mechanical properties.

c).The tensile and flexural modulus reduction is more in hygrothermal aging because of temperature is a key factor for accelerated aging in the processes of water diffusion and chemical degradation.

d) This results shows that surface and edge coatings has a protective against changes of mechanical properties of GFRP composite laminates.

e) It is worth noticing that aging at elevated temperatures strength degradation is more in salt water exposure compared to simple water.

f).It is clear that retention ratio gradual decreases for painted specimens and rapid decreases in unpainted specimens under tensile loading with different environmental conditions.

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