The Effect of Moisture on the Properties of Glass Fiber Polymer Matrix Composites with Mos$_2$ and Caco$_3$

Kadiyala Jhansi, Kondru Nagendra Babu, Lokavarapu Bhaskara Rao

Abstract: ***The mechanical properties and water absorption behavior of a pure glass fiber reinforced epoxy matrix and a glass fiber reinforced epoxy filled composites immersed into a tap water were investigated. The main purpose of this experiment is addition of two different powdered fillers ($CaCO_3$ and MoS_2) into the epoxy matrix and comparing the properties of pure GFRP and filled GFRP. The composites specimens with fillers absorb less water when compared to pure GFRP specimens at room temperature. Water absorption curves and equilibrium moisture content were determined. The composites exhibit a positive deviation from the Fickan's law with the addition of fillers into the matrix. The influence of water uptake has significant effect on the reduction of mechanical properties. It is observed that 3% filled MoS_2 in epoxy matrix has less uptake of water and the tensile strength decreased is 3% , flexural strength decreased up to 18% and shear strength is 42% decreased when compared to $CaCO_3$ filled composites and unfilled glass fiber reinforced polymer composite.***

Keywords**: Fillers, Water absorption, Fickan's law**

I. INTRODUCTION

The effect of moisture content and loading has direct influence on the properties of glass fiber reinforced polymer composites [1]. Numerous investigations are done and studied to find the effect of environment attack on the composite materials [4]. Among the other fibers, glass fiber is widely used because of low cost and it degrades to only some environmental attacks [5]. The main problem with fibrous polymer composite its visco elastic behavior results in failure and highly sensitive to environmental conditions [3]. To reduce the failure rate of polymer composites when exposed to different environmental conditions filler/additives etc. are added to improve the durability of composites [6].The addition of powders of different compounds like carbon nanotubes [6], silver nano particles [10]-[15], nano clay [16], Al_2o_3 [17], PMMA [20] to epoxy matrix believed to produce the new composites of improved thermal and mechanical properties etc. compared to the existing counter parts with relative to the cost effective fillers [21] The geometrical shape, shape of the powdered fillers has direct influence on the dimensional stability, processibility, thermal and mechanical properties of the composite [22].This may leads to the pave way to the new applications and solutions in the industries. The improvement in the properties leads the fillers to tolerate the some of the tension and applied bending load [23] enhances the various mechanical properties of the end product [25]-[29]. $CaCO_3$ is one of the extensively used and it is incorporated in the matrix in the plastic industry to improve the mechanical properties of the end product [30]. Carbon black is added to the matrix to improve the stiffness of the material and to the costs [31]. The moisture absorption may induce plasticization or hydrolysis, when may leads to the change in the microstructure of the matrix and affects the effects the thermal, mechanical and physical properties of the composites [32]-[35]. To overcome these effects in this investigation calcium carbonate and molybdenum disulphide are added to the epoxy matrix to balance the properties of the material in different environmental conditions.

II. EXPERIMENTAL PROCEDURE

A. Raw materials and processing of FRP

The raw materials required in this study are listened in table 1. The preparation of composite takes place in 5 steps. Initially the powder fillers $CaCO_3$/MoS_2 of required quantity is sonicated in acetone in bath Sonicator for 45 min for easily dispersion of powder particles in the epoxy matrix. The Sonicated powder is removed and dried to remove the moisture content present in it. Epoxy matrix is pre heated for 30 min at 75˚C in hot air oven. The powdered fillers are added into the epoxy and stirred for 45 min to reduce the air bubbles present in the epoxy and uniform dispersion takes place. The accelerator is added to the matrix at room temperature in the ratio 10:1. The laminate is prepared by the stacking of fabric layers.

Table- I Raw materials and suppliers

SNo.	Raw materials required	Supplier / manufacture
1	Matrix-epoxy	Atul. Industries, India
2	Reinforcement-E-glass fabric	CMS fiber industry, Hyderabad

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3	$CaCO_3$ filler	Pioneer chemical industries, Hyderabad
4	MoS_2 filler	Pioneer chemical industries, Hyderabad

B. Water immersion test

The water immersion tests are carried out on the pure GFRP composites and filler filled composites. The PH value for the tap water is 8.8. The tests are carried out based on American stands ASTM D570-98. The each sample plate is molded according to size 30 x 30 mm. 3 specimens are prepared for each plate (i.e. 8 plates -24 specimens) and tested under same condition. All the specimens are kept in oven for 6 hrs at 75°C to reduce the weight of the specimens, repeatedly done until the weight of the specimens reduce to less than 0.1mg. The dried specimens are immersed in water tub at room temperature. The experiment is carried out for 30 days. The samples are weighted regularly at different time intervals. The percentage of mass gain is calculated by equation (1).

$$m_t = \frac{m - m_0}{m_0} \times 100\ \%$$

Where m_t is percentage of moisture gain in time't'

m Is mass of the specimen at time't'

SPECIMENS	WATER ABSORPTION (%)		
	7 DAYS	15 DAYS	30 DAYS
PURE GFRP	0.1	0.24	0.36
1%$CACO_3$ + GFRP	0.05	0.33	0.12
3%$CACO_3$ + GFRP	0.01	0.22	0.12
5%$CACO_3$+ GFRP	0.01	0.11	0.23
7%$CACO_3$+ GFRP	0	0.12	0.12

Table - II water absorption behavior of filled and unfilled GFRP composites for 30 days

m_0 Is mass of the specimen in dry condition

C. Mechanical tests

The flexural, tensile and shear strength properties were tested on the computerized universal testing machine with a cross head speed of 5mm/min. The specimens are grouped into 9 group of different weight composition of filler contents, each group has 3 samples. The samples are immersed in tap water for 9, 15, 30 days at room temperature before testing. The flexural and tensile tests are conducted according to American standards ASTM D7264 and ASTM 3010 of span length 72 and 80 mm. Inter laminar shear strength test is conducted according to ASTM D2344-13 Mode-2. Each test has 27 samples of 9 groups; total 81 samples under goes mechanical tests.

C. Water absorption behavior description (Fickan's law)

For short term water immersion test water absorption behavior can be determined by Fickan's law. The diffusion coefficient is given as

$$D_z = \pi\{h|4 \times (\%M_m\}\hat{}2 \times \{\%M_2 - \%M_1|\sqrt{t_2} - \sqrt{t_1}\}\hat{}2$$

Where M_1 and M_2 are the percentages of water absorbed in time t_1 and t_2 sec

D_z is diffusion coefficient

l and w are the length and width of the specimen according to ASTM standards

h is the thickness of the specimen

M_m is the %age of moisture content in Fickan's region

$$D = \frac{D_z}{\left[1 + \frac{h}{l} + \frac{h}{w}\right]\hat{}2}$$

D is the corrected diffusion constant.The results of the water absorption of filled GFRP composites and unfilled GFRP composite specimens for 30 days are shown in figure 1 and figure 2 and follows Fickan's law of diffusion. According to figure 1 it is observed that the water absorption is found more for unfilled glass fiber reinforced polymer composites than the filled glass fiber reinforced polymer composite about 0.36% more for 30 days and it has been increasing.

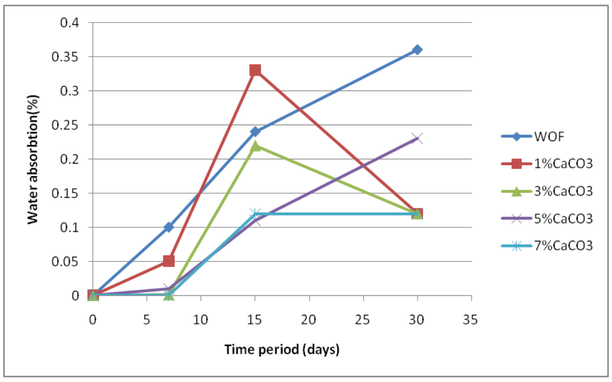

Fig 1 Water absorption curves of $CaCo_3$ filled composites for 30 days

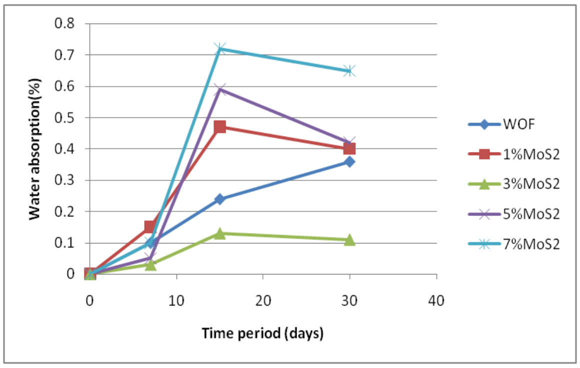

Fig 2 Water absorption curves of MoS_2 filled composites for 30 days

From the table II Comparing to different weight filled $CaCO_3$ epoxy composite and found that 7% filled $CaCO_3$ absorbed less water into epoxy matrix is about 0.12% it remains constant and listened in table 2. According to figure 2 it is observed that pure GFRP has more water absorption for 30 days is 0.36% and minimum is for 3% weight filled MoS_2 polymer composite is about 0.11% as shown in table III.

Table - III water absorption behavior of filled and unfilled GFRP composites for 30 days

SPECIMENS	WATER ABSORPTION (%)		
	7 DAYS	15 DAYS	30 DAYS
PURE GFRP	0.1	0.24	0.36
1% MoS_2+ GFRP	0.15	0.47	0.4
3% MoS_2+ GFRP	0.03	0.13	0.11
5% MoS_2+ GFRP	0.05	0.59	0.42
7% MoS_2+ GFRP	0.1	0.72	0.65

composites (from table 5) are 394.33N/mm^2 and 373.32N/mm^2. The tensile strength is found maximum at 3%MoS_2 is 323.71N/mm^2.

III. RESULTS AND DISCUSSION

Evaluating the mechanical properties of $CaCO_3$ /MoS_2 filled GFRP composites and unfilled GFRP composites after 30 days. The tensile strength, shear strength and flexural strength results are shown in table 4 and table 5. It is observed that from the table IV and table V the tensile strength, flexural strength and shear strength decreases under water absorption. The tensile strength of specimens is found maximum for pure GFRP and 3% $CaCO_3$ filled GFRP composite specimen is 394.33N/mm^2 and 350.76N/mm^2. After 30 days of water immersion the tensile strength is found decreasing as the filler percentage increases and found maximum 3% $CaCO_3$ filled GFRP composite specimen and pure GFRP composite is 330.67N/mm^2 and 350.55N/mm^2 is shown in figure4.

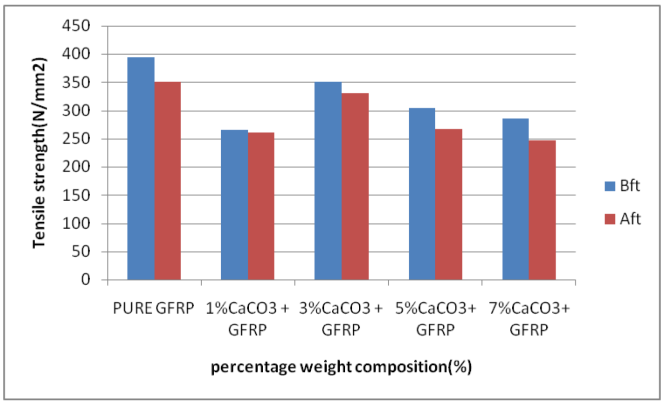

Fig 3 representing the tensile strength V_s percentage weight composition of $CaCO_3$ filled under tension

From the figure 5 it is observed that the flexural strength is found maximum before water absorption and decreases with increase in the filler content. The maximum tensile strength is observed for before water absorption is pure GFRP and at 3%MoS_2 filled GFRP

Table- IV Tensile and flexural and ILSS properties of GFRP and $CaCO_3$ filled GFRP composites

Specimens	Mechanical Tests					
	Average Tensile Strength(N/mm^2)		Average flexural strength((Mpa)		Averages ILSS(Mpa)	
	Before	After	Before	After	Before	After
PURE GFRP	394.33	350.35	458.74	162.81	34.31	13.37

1%CaCO$_3$ + GFRP	265.8	260.22	528.14	229.52	34.79	11.76
3%CaCO$_3$ + GFRP	350.76	330.67	360.53	310.46	31.56	19.36
5%CaCO$_3$+ GFRP	303.56	266.13	345.51	340.63	30.55	11.33
7%CaCO$_3$+ GFRP	286.09	246.43	276.78	215.92	30.3	9.19

Table -V Tensile and flexural and ILSS properties of GFRP and MoS$_2$ filled GFRP composites

Specimens	Mechanical Tests					
	Average Tensile Strength(N/mm^2)		Average flexural strength((Mpa)		Averages ILSS(Mpa)	
	Before	After	Before	After	Before	After
PURE GFRP	394.33	350.35	458.74	162.81	34.31	13.37
1% MoS$_2$ + GFRP	304.91	295.31	348.09	227.6	34.01	10.33
3% MoS$_2$ + GFRP	373.32	323.71	339.78	276.94	29.34	16.93
5% MoS$_2$+ GFRP	321.41	291.16	332.76	127.32	28.66	9.33
7% MoS$_2$+ GFRP	290.67	270.32	320.67	120.26	26.06	9.01

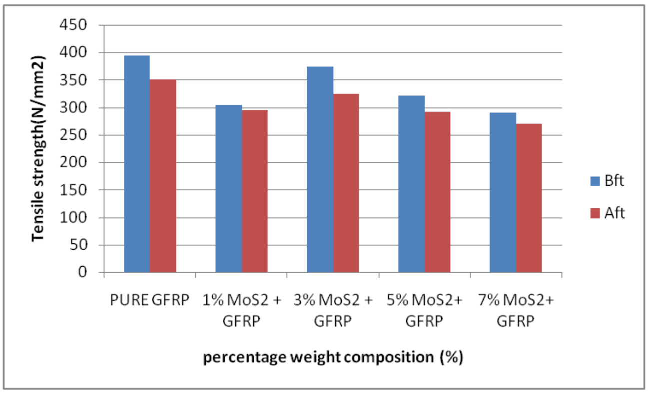

Fig 4 representing the tensile strength V$_s$ percentage weight composition of MoS$_2$ filled under tension

The flexural strength of specimens is found maximum for pure GFRP and 1% CaCO3 filled GFRP composite specimen is 458.74MPa and 528.14MPa. After 30 days of water immersion the flexural strength is found decreasing as the filler percentage increases and found maximum 5% CaCO3 filled GFRP composite specimen and pure GFRP composite is 340.63MPa and 162.81MPa is shown in figure5.

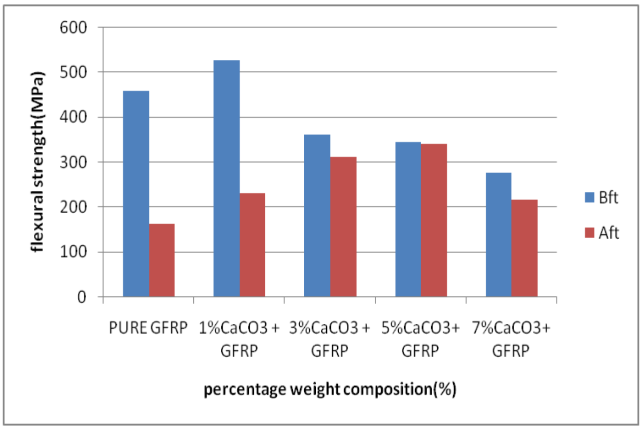

Fig 5 representing the flexural strength V_s percentage weight composition of $CaCO_3$ filled under bending

From the figure 6 it is observed that the flexural strength is found maximum before water absorption and decreases with increase in the filler content. The maximum flexural strength is observed for before water absorption is pure GFRP and at 1%MoS_2 filled GFRP composites (from table 5) are 458.74 MPa and 348.09MPa. The flexural strength is found maximum after water absorption is at 3%MoS_2 and pure GFRP is 131.65Mpa and 162.81MPa.

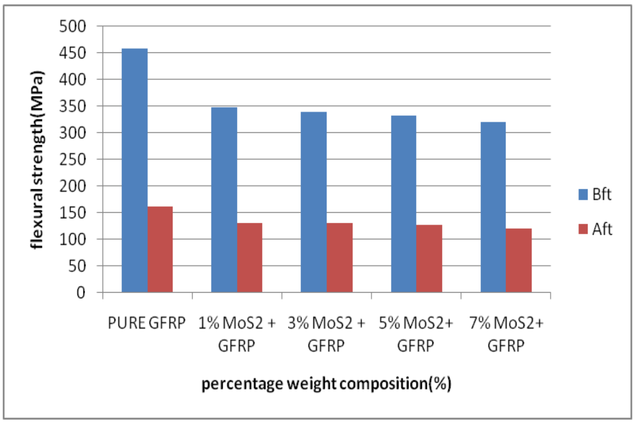

Fig 6 representing the flexural strength V_s percentage weight composition of MoS_2 filled under bending

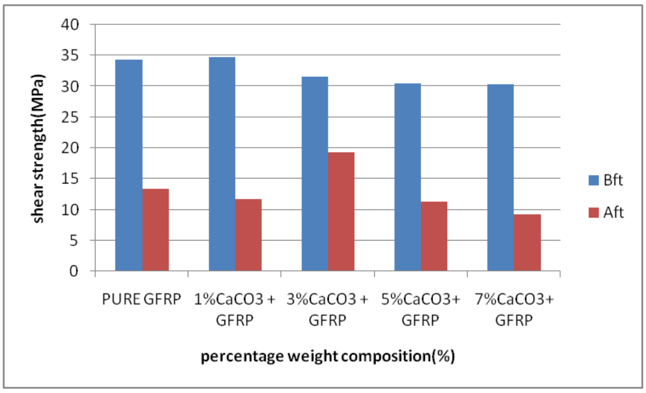

Fig 7 curves of flexural strength Vs percentage weight composition of $CaCO_3$ specimens under short beam bending

The shear strength of specimens is found maximum for pure GFRP and 1% $CaCO_3$ filled GFRP composite specimen is 34.31MPa and 43.79MPa. After 30 days of water immersion the shear strength is found decreasing as the filler percentage increases and found maximum 3% $CaCO_3$ filled GFRP composite specimen and pure GFRP composite is 19.36MPa and 13.37MPa is shown in figure7.

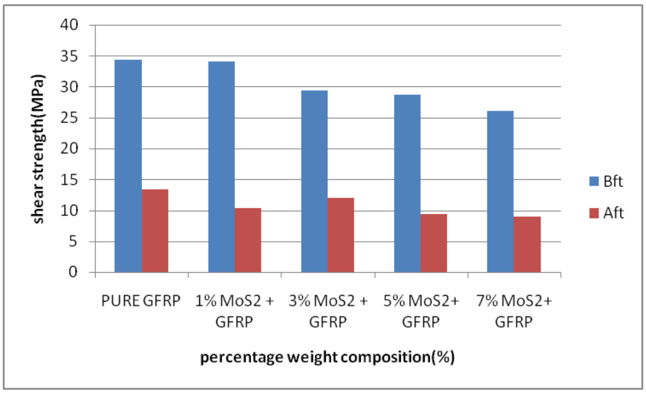

Fig 8 curves of flexural strength Vs percentage weight composition of $CaCO_3$ specimens under short beam bending

From the figure 8 it is observed that the shear strength is found maximum before water absorption and decreases with increase in the filler content. The maximum shear strength is observed for before water absorption is pure GFRP and at 1%MoS_2 filled GFRP composites (from table 5) are 34.31 MPa and 34.79MPa. The shear strength is found maximum after water absorption is at 3%MoS_2 and pure GFRP is 16.93MPa and 13.31MPa.

IV. CONCLUSION

The effect of two fillers MoS_2 and $CaCO_3$ on mechanical properties of fiber glass reinforced polymer composites before and after water absorption was investigated. The following are the conclusions drawn from the study:

- The percentage decrease of tensile strength, flexural strength and shear strength of pure GFRP composite after 30 days of water absorption is 11%, 64%and 59%.
- The percentage decrease in the mechanical properties of $CaCO_3$ filled composite after water immersion is found minimum uptake of water in 3%$CaCO_3$ is 13%, 61%, and 42%.
- The percentage decrease in the mechanical properties of MoS_2 filled composite after water immersion is found minimum uptake of water in 3%$MoS_2$is 13%, 18%, and 42%.
- It is observed that when compared to over all composites, MoS_2 filled composites has maximum

mechanical properties before water absorption and minimum water intake for 3% filled composite materials.

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