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Analysis of Tensile Strength of Different Combination of FRP Material under Seawater Conditioning

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Abstract: The analysis of tensile strength with different combination material of Fiber Reinforced Polymer (FRP) under seawater. Fiber reinforced polymer are composite materials made out hardening or room temperature curing resin as matrix together with reinforcement materials. Seawater is salty and it has different density with fresh water, lake or river. Floating structure is something that floats on the surface of a fluid or space without sinking. The specimens or samples were made from the different combination of FRP material which is tissue mat, chopped strand mat, woven roving, resin, catalyst and color pigment. An immersion test was run in minimum of 30 days. The tensile test was carried out was based an axial stress test for the same size specimens of five for each different combination of material. This study has identified that the combination of specimens 3 has the highest tensile test.

Key words: Tensile, FRP, seawater, immersion, immersion test, combination

INTRODUCTION

Floating structure is something that floats on the surface of a fluid or space without sinking. The floating structure can be easily constructed, exploited and relocated, expanded or removed which make these structures are cost-effective and environmentally friendly floating artificial islands as stated by Papaioannou *et al*. (2013). These structures can and are already being used for floating bridges, floating piers, floating performance stages, floating airports, even habitation and other purposes as mentioned by Wang *et al*. (2007).

Mostly, a floating structure is placed on lakes and rivers because of the environmental effect are different from the sea. The different of environment such as sea and lake will also affect the floating structure surface at sea and lake.

The environments at sea are wavy with unpredictable wave with salt water and a density of 1.025 t/m^3. At the lake the water condition is calm, type of water is fresh water and the density is 1.000 t/m^3. The different condition of water will affect on the surface of the floating structure which will make the surface rough, corrode and damage.

Nevertheless, loads also will affect on the strength of floating structures. The structures are subjected to different types of load and due to different causes and can be classified into sixth which are dead loads, live loads, wind load, snow load, seismic load and impact load.

The strength of the structure is important to avoid the cracking and damage. In successful composite there must be adequate bonding between fiber and matrix and this bonding may be either physical or chemical. The main function of the matrix material is to hold the fiber in the correct position so that they carry the stress applied to composite as well as to provide adequate rigidity. At the same time the matrix protects the fiber from surface damage and from the action of the environment.

The strength design is done to ensure that the stress at any point in the element do not exceed the permissible value of the material that will be used as reported by Suramanian (2010). Most applications are in diminutive commercial vessels and recreational craft with composites utilized in offshore structures rapidly growing as stated by Nita and Opran.

Fiber reinforced polymer can be used as an alternative material in the construction of floating structures. FRP can provide a solution in term of better strength capacity anti-corrosion and possible less maintenance during service.

Composite are able to meet diverse design requisite with consequential weight, preserving as well as high strength-to-weight ratio as compared to conventional materials (Alexandra, 2012). The proportions of shear strength and compressive strength to principal strength are significantly less for most othrotropic composite laminates than steel or aluminum plate.

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Nevertheless the stcaking sequence and orientation of laminates will improve as mentioned by Sideridis and Papadopoulos (2004) had also succefully determined the shear strength of unirectional glass fiber reinforced epoxy resin composite of different fiber directions using the short beam three-point bening test.

MATERIALS AND METHODS

Fiber reinforce polymer

Introduction of fiber reinforced polymer: Fiber reinforced polymer are composite materials made out heat-hardening or room temperature curing resins as matrix together with reinforcement materials. There are three main groups of most common man-made composites Fiber Reinforced Polymer (FRP), Ceramic Matrix Composite (CMC) and Metal Matrix Composite (MMC) as mentioned by Hamid *et al.* (2010).

Combination of material: The fiber for the most part possesses 30-70% of the matrix volume in the composites. The fibers can be chopped, stitched, woven and braided. The most widely recognized types of fibers utilized as advanced composites for structural applications are the fiberglass, carbon and aramid. The fiberglass are the least expensive and carbon being the most expensive.

Niroumand mentioned that the glass fibers are divided into three classes C-glass, E-glass and S-glass The C-glass is for high corrosion resistance and it is unusual for civil engineering applications. The E-glass is designed for electrical use and the S-glass for high strength. Table 1 shows the typical properties of E-glass and S-glass.

Umair (2006) mentioned that the resin is another important constituent in composites. The two classes of resins are the thermoplastics and thermosets. A thermoplastic resin remains a solid at room temperature. It liquefies when heated and solidifies when cooled. The long-chain polymers do not chemically cross linked.

The epoxies utilized as a part of are mainly the glycidyl ethers and amines. Epoxies are generally found in marine, electrical, automotive and appliance applications as mentioned by Sen *et al.* (2012). The high viscosity in epoxy resins limits it use to certain processes such as hand lay-up, molding and filament winding.

A variety of added substances or call additive are utilized as a part of the composites to improve the material properties, aesthetics, manufacturing process and performance.

The combination of material that has used the color pigment or gel coat (Polycor GP-H) were impregnated with epoxy resin (3554A) with 1% Methyl Ethyl Ketone Peroxide (MEKP) as a catalyst. The mixed of color pigment and resin were according to designed configurations.

Table 1: Typical properties of E-glass and S-glass Sideridis and Papadopoulos (2004)

Typical properties	E-glass	S-glass
Density (g/cm^3)	02.60	02.50
Young's modulus (GPA)	72.00	87.00
Tensile strength (GPa)	01.72	02.53
Tensile elongation (%)	02.40	02.90

Table 2: Size of specimen

Fiber orientations	Width (mm)	Length (mm)	Thickness ABS (mm)
Balanced and symmetric	25	250	2.5

Table 3: Combination of material for each specimen

Specimens	Materials
1	Tissue mat FRP+resin+catalyst+color pigment
2	Chopped strand mat FRP+resin+catalyst+color pigment
3	Woven roving FRP+resin+catalyst+color pigment
4	2 Tissue mat FRP+4 chopped strand mat FRP+1 woven roving+resin+catalyst+color pigment
5	2 Tissue mat FRP+chopped strand mat FRP+3 woven roving+resin+catalyst+color pigment

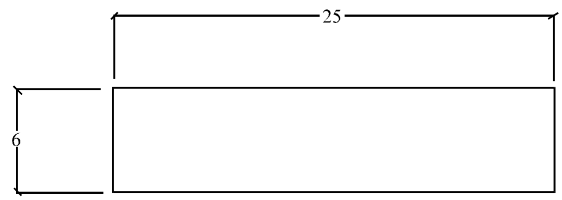

Fig. 1: Side view of the specimen size

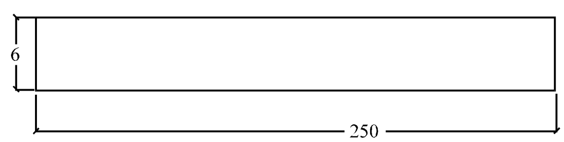

Fig. 2: Front view of the specimen size

Specimen preparation: The testing requires at least 5 specimens for each test condition unless useable result can gained through the use of less. These test specimen used the fiber reinforced polymer.

The standard tensile specimens were prepared to have dimensional and tolerance for 5 different combinations of materials. All specimen is a coupon without tab shapes and same thickness as shown in Fig. 1 and 2 but all have different material combination as shown in Table 2 and 3. It is selected based on ASTM D3930 and American Bureau Shipping rules (ABS).

Specimen 1 until specimen 5 used the color pigment or gel coat (Polycor GP-H) which were impregnated with epoxy resin (3554A) with 1% Methyl Ethyl Ketone Peroxide (MEKP) as catalyst. The mixed of color pigment

Fig. 3: Specimen 1 tissue mat

Fig. 4: Specimen 2 CSM 450

and resin were according to the designed configurations. Then, one plate of glass was used to give a nice decorative surface. Prior to the process, Mirror Glaze® mold release wax was applied onto the glass to prevent the unwanted bonding between the materials and the glass surfaces. The coated were cured at room temperature for 24 h.

Specimen 1 used the tissue mat FRP were impregnated with epoxy resin (3554A) with 1% Methyl Ethyl Ketone Peroxide (MEKP) as catalyst. The ratio of resin to fiber is fixed at approximately 2:1. The laminated composite were cured at room temperature for 24 h.

Finally the laminates were cut according the specimen size using a Tenoning and Squaring machine. The prepared specimen size is 6×25×250 mm. Figure 3 shows the sample Specimen 1.

Specimen 2 and 3 used the chopped strand mat (KCM 450A) and woven roving (XD-600) of E-glass fiber which were impregnated with resin (3554 A) with 1%

Fig. 5: Specimen 3 woven roving

Fig. 6: Specimen 4

Methyl Ethyl Ketone Peroxide (MEKP) as catalyst. The fiber and resin were laminated layer by layer. Figure 4 and 5 show a cured samples of Specimen 2 and 3. Specimen 4 used the tissue mat, chopped strand mat (KCM 450A) and woven roving (XD-600) which were impregnated with resin (3554A) with 1% Methyl Ethyl Ketone Peroxide (MEKP) as catalyst. The fiber and resin were laminated layer by layer started and ended with tissue mat. The next laminated are two chopped strand mat one woven roving and two chopped strand mat as shown in Fig. 6.

Specimen 5 used the tissue mat, chopped strand mat (KCM 450A) and woven roving (XD-600) which were impregnated with resin (3554A) with 1% Methyl Ethyl Ketone Peroxide (MEKP) as catalyst. The ratio of resin: fiber is fixed at approximately 2:1. The fiber and resin were laminated layer by layer started and ended with tissue mat. The next layered are one chopped strand mat, one woven roving and repeat 2 times (Fig. 7).

Material specimen processes for each specimen are made one at a time and the laminate sequence and orientation is shown in Table 4.

Table 4: Stacking sequence and orientation (Symmetry laminate)

Specimens	Stacking sequence	Orientation (°)
1	Tissue mat (T)	0
2	Chopped Strand Mat (CSM)	90
3	Woven Roving (W/R)	90
4	T+2CSM+W/R+2CSM+T	90
5	T+CSM+W/R+CSM+W/R+CSM+W/R+T	90

Fig. 7: Specimen 5

Immersion test: The specimens were immersed in salt water to simulate seawater environment. The Specimen 1 until Specimen 5 were immersed in the basin with one condition which was sea water. The conditioning in saltwater was conducted in Material Laboratory of UniKL MIMET for 30 days. The specimen for immersion test have three specimens for each test.

Specimen should be in positioned as to avoid specimen to specimen contact while in the basin. Enough fluid tmust be added to immerse the specimen. The fluid level was checked every 7 days. If more than 5% of the test fluid evaporates from the test basin, fluid were added to maintain the level and composition of the fluid. The room temperature of 25±2°C was maintain by using the air conditioner.

Tensile test: A Universal Testing Machine (UTM) used was Galdabini Quasar 100. The UTM have two-column rigid system with 100 kN maximum capacity and it is suitable for metals, plastics, composites and other materials.

Flexible and modular design for easy future expansion and the key technical advantages include extremely high resolution of load and stroke readings as well as minimum test speed of 0.0005 mm/min for the high performance and most accurate results.

The tensile test was conducted at material laboratory UniKL MSI by using Galdabini Qausar 100 as shown in Fig. 8. Before the experiment was carried out the specimen thickness and gauge length were measured and numbered for identification as shows in Fig. 9.

Table 5: Number of specimens

Specimens	Stacking sequence	Quantity
1	Tissue (T)	3 (1a-c)
2	Chopped Strand Mat (CSM)	3 (2a-c)
3	Woven Roving (W/R)	3 (3a-c)
4	T+2CSM+W/R+2CSM+T	3 (4a-c)
5	T+CSM+W/R+CSM+W/R+CSM+W/R+T	3 (5a-c)

Fig. 8: Example of numbered for Specimen 1

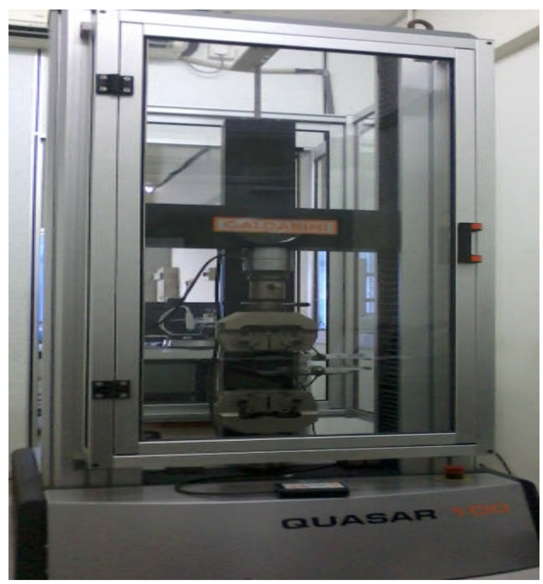

Fig. 9: Universal testing machines Quasar 100

Table 5 shows the numbers of coupon for each type of specimens required for the testing. Specimen that has been placed accurately was with vertical load of maximum 100 kN load capacity. The related data and observation were recorded.

RESULTS AND DISCUSSION

The specimens stacking sequence and orientation use either tissue, chopped strand mat or woven roving

Table 6: Result of tensile test with immersion seawater

Specimens	Load (N)	Stress σ (MPa)	Strain(ε)
1	6539.00	43.59	0.46
2	14173.64	94.49	0.22
3	40949.07	272.99	0.28
4	17155.50	114.37	0.23
5	16594.50	110.63	0.17

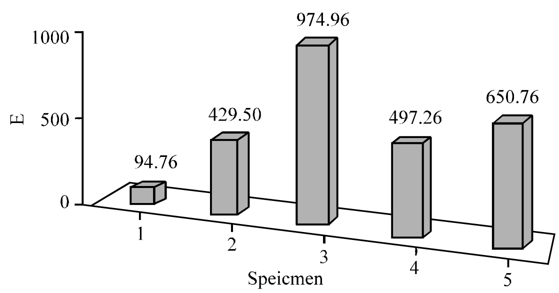

Fig. 10: Graph young modulus

fiber glass with (0/90) orientation bind together with epoxy (3554A) and catalyst. The detail result for each specimen are shown in Table 6.

Strength achieved by the specimen is in the range of 42-273 MPa. Specimen 3 is the specimen that achieved the highest strength which is 272.99 MPa among all five specimens. The specimen that attained the lowest ultimate strength is Specimen 1 which only accomplish 43.59 MPa. The average of strength was Specimen 2, 3 and 5 which are 94.49, 112.37 and 110.63 MPa.

The load of tensile test result with Salt Water (SW) immersion were Specimen 3 with maximum load of 987.23 N. The Specimen 1 has minimum load which is 94.76 Pa. Meanwhile the strain response to the maximum load is 0.28. Specimen 5 has a minimum strain of 0.17 and Specimen 1 has maximum strain which is 0.46. Specimen 2, 4 and 5 had an average strain which are 0.22, 0.23 and 0.17. The result for specimen under seawater immersion is shown in Table 6.

According to the graph of stress-strain as shows in Fig. 10 the modulus of elasticity can directly be calculated. The Specimen 3 attained the highest modulus of elasticity which is 974.96 Mpa among five specimen. Specimen 1 is the specimen that achieved the lowest modulus of elasticity which only 94.76 MPa. The average modulus of elasticity was Specimen 2, 4 and 5 which are 429.95, 479.26 and 650.76 MPa. As proven by the experimental results the change in woven roving orientation angle and combination of material has significantly improve the tensile strength of Specimen 3 with highest tensile strength average of 272.99 MPa and the maximum load was 40.95 kN.

CONCLUSION

According to ASTM D3039, FRP fabric properties is tested by tensile test with immersion under seawater. The tensile test result for stress vs strain it was liner elastic behavior to failure, no yielding, higher ultimate strength and lower strain at failure. The results of experimental work showed that the behavior of Fiber Reinforced Polymer (FRP) combination with immersion under seawater capable to sustain carrying capacity to the ultimate strength for Specimens 3 was 272.99 MPa. This study has identified that the combination of Specimen 3 has the highest tensile test. The experimental research has proved the result of the experiment within range theory calculation to identify the highest tensile test for various condition and exposure.

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