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Mechanical Properties of Virgin and Recycled Glass Fiber Polyester Composite

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Abstract*—This work studied recycling of glass fiber for new products (second use). The main source of recycled glass fiber is factory scrap and applications waste (such as water tank waste). In this work waste of glass fiber is burned to separate glass fiber waste from other materials. Hand lay-up method is used for fabrication one and two layers of virgin glass fiber/polyester composite and also for recycled glass fiber/polyester composite. Mechanical tests are applied such as tensile test, bending test and hardness test for evaluations the properties of varies samples. The results showed the composite containing recycled glass fiber has low properties compare to virgin.*

Keywords— Glass fiber; Polyester; Composite; Recycle.

1. INTRODUCTION

FRP scrap costs fabricators in two ways disposal costs and opportunity costs. Disposal costs are what people conventionally think of when the topic of waste cost is mentioned. Disposal costs include transport and landfill fees. An often-overlooked scrap cost is the opportunity cost of materials thrown away that might have been used to produce a saleable product. The opportunity to capture revenue is lost every time scrap goes in the trash. To encourages waste reduction as the best way to deal with waste. Because waste reduction lowers both disposal and opportunity cost, it tends to have a larger economic payback than end-of-pipe treatments like recycling. However, even the best available FRP manufacturing technology still generates a certain amount of scrap. To address the interest in scrap recycling, this document strives to summarize the current state of FRP recycling. This has been accomplished via a review of the relevant literature and through discussions with people who have tried to recycle FRP scrap in the past.

Solid waste generated in the FRP manufacturing process is a matrix of cured polymer resin and fiber reinforcement material. The chemical structure of the polymers used, and the fiber and filler content of FRP scrap, make recycling more complex than typical thermoplastic recycling. The first problem with FRP scrap recycling is the use of thermoset resins. Thermoset resins are liquids that cure to a solid through a chemical reaction that cross links the resin molecules. This curing reaction is non-reversible; the cured solid does not return to its original liquid form through heating as do thermoplastics. Unlike thermoplastics, the FRP scrap cannot be melted down and remolded, as is often done in plastic recycling. A useful analogy for comparing thermosets to thermoplastics would be to compare cooking an egg to freezing water. Like the frozen water, a thermoplastic material can be melted and "re-frozen," but the cooked egg (cured thermoset) cannot be Trans formed back to the raw state. The second complicating factor in FRP recycling is the filler and fiber content of the scrap. Fillers are added to FRP resins to reduce the amount of resin needed to produce a part. This reduces cost and styrene emissions. Fillers can also be used to improve fire-resistance or affect appearance. Fibers are used in composite products to add strength. The physical properties of these fibers determine the strength of the finished part. Two of the critical fiber properties that contribute to strength are fiber length and the lack of surface defects in the fibers such as cracks and chips. Any reduction in fiber length or introduction of surface defects by a recycling system will reduce the value of the recycled material. A recycling system for FRP would have to be designed to recover and reuse the fiber and filler content of the scrap.

2.MATERIALS AND METHODS

2.1 Glass fiber

The glass fibers are made of various types of glass depending upon the fiber glass use. These glasses all contain silica or silicate, with varying amounts of oxides of calcium, magnesium, and sometimes boron. To be used in fiber glass, glass fibers have to be made with very low levels of defects. Fiber glass is a strong lightweight material and is used for many products. Although it is not as strong and stiff as composites based on carbon fiber, it is less brittle, and its raw materials are much cheaper. Its bulk strength and weight are also better than many metals, and it can be more readily molded into complex shapes. Other common names for fiber glass are glass-reinforced plastic (GRP), glass-fiber reinforced plastic (GFRP).

Table 1: Glass fiber specification

Quality index		Index value	Mean value
Fabric weave		Plain weave	Plain weave
Width (CM)		100	100
Thickness (CM)		0.24	0.235
Mass per unit area (g/m^2)		200	195
Density (/cm)	Warp	8	8
	Weft	7	7
Tensile breaking strength N/50*200mm	Warp	1300	2865
	Weft	1100	2559
Moisture content %		/	0.09
Oil content %		/	0.71

2.2 Polyester resins

Polyester resins are unsaturated synthetic resins formed by the reaction of dibasic organic acids and polyhydric alcohols. Polyester resins are used in sheet molding compound, bulk molding compound and the toner of laser printers. Wall panels fabricated from polyester resins reinforced with fiberglass so-called fiberglass reinforced plastic (FRP) are typically used in restaurants, kitchens, restrooms and other areas that require washable low-maintenance walls.

Table 2: Unsaturated polyester resin properties

Property Unit	Property Unit
Density 1200(kg/m^3)	Density 1200(kg/m^3)
Thermal conductivity 0.17(W/m. ^oC)	Thermal conductivity 0.17(W/m. ^oC)
Tensile strength 70.3 -103(MPa.)	Tensile strength 70.3 -103(MPa.)
Modula's of elasticity 2.06 – 4.41(GPa.)	Modula's of elasticity 2.06 – 4.41(GPa.)

3. EXPERMENTAL WORK

3.1 Manufacturing method

There are several materials were used in this work with quantities, using hand lay-up method random glass fiber (E Glass - virgin & recycled) as fabric with unsaturated polyester was used as matrix in present of Catalyst (methyl ethyl ketone) peroxide and Wax.

3.2 Testing methods

After the samples were manufactured, it was cut according to stander size by cutting tools, after that at room temperature varies tests were applied such as tensile, bending and hardness.

4.TESTING AND RESULTS

4.1Tensile test

4.1.1 Virgin samples (one layer)

Table 3 and Fig 1 show the tensile strength of one-layer virgin samples. The curve illustrates the tensile strength of the composite fabric have linear behavior before the failure point, and the maximum force 0.557KN, before a drop down happened incurring failure mode.

Table 3: Tensile test of virgin samples (one-layer)

Sample no	Force (KN)	Stress (MPa)	Elongation (%)	Modulus (MPa)
1	0.657	92.593	4.94	1814.4
2	0.473	60.512	3.60	2268.3
3	0.541	67.667	3.53	2621.2
Ave	0.557	73.590	4.02	2234.6

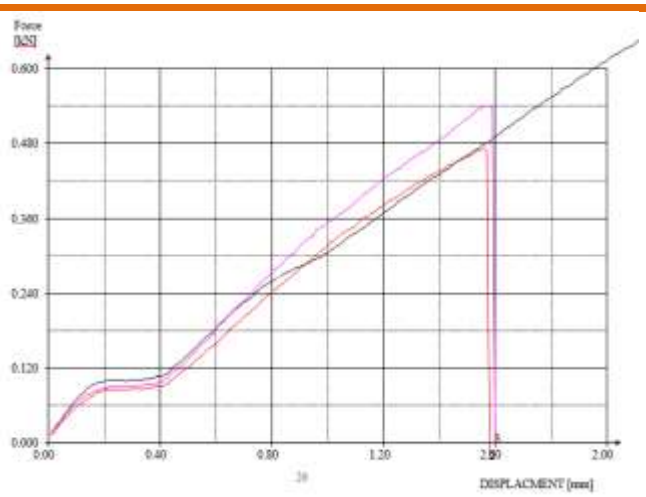

Fig. 1. *Tensile test of virgin samples(one-layer)*

4.1.2 Virgin samples (two layers)

Table 4 and Fig 2 show the tensile strength of two-layer virgin samples. The curve illustrates the tensile strength of the composite fabric have linear behavior before the failure point, and the maximum force 0.964KN, before a drop down happened incurring failure mode.

Table 4: Tensile test of virgin samples (two-layers)

Sample No	Force (KN)	Stress (MPa)	Elongation (%)	Modulus (MPa)
1	1.102	99.221	4.01	3047.875
2	0.868	62.520	0.00	0.00
3	0.922	66.003	3.35	2114.264
Average	0.964	75.914	3.68	1458.786

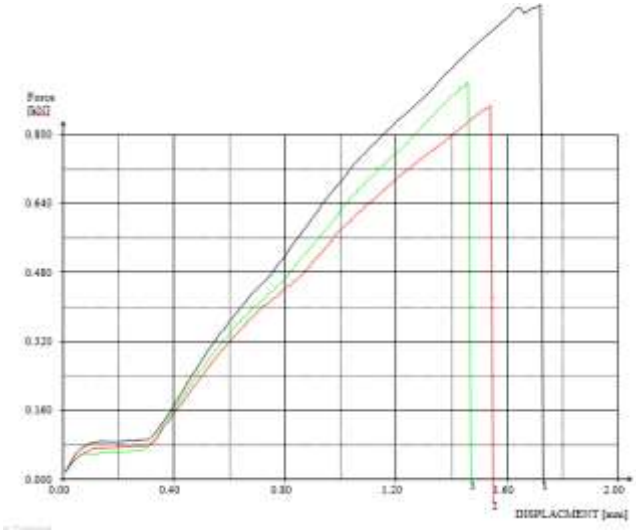

Fig. 2: *Tensile test of virgin samples (two-layers)*

4.1.3 Recycled samples (one layer)

Table 5 and Fig 3 shows the tensile strength of one-layer recycled samples. The curve illustrates the tensile strength of the composite fabric have linear behavior before the failure point, and the maximum force 0.282KN, before a drop down happened incurring failure mode.

Table 5: Tensile test of recycled samples (one-layer)

Sample no	Force (KN)	Stress (MPa)	Elongation (%)	Modulus (MPa)
1	0.274	23.263	3.26	514.806
2	0.314	24.681	1.79	781.964
3	0.259	14.517	2.86	426.454
Average	0.282	20.820	2.63	574.426

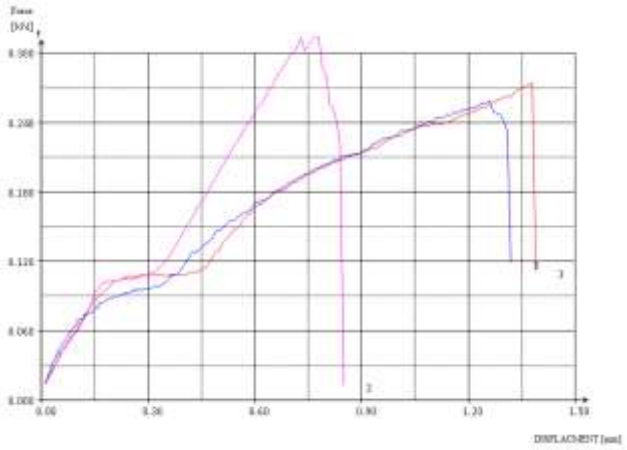

Fig. 3: *Tensile test of recycled samples (one-layers)*

4.1.4 Recycled samples (two layer)

Table 6 and Fig 4 show tensile strength of two-layer recycled samples. The curve illustrates the tensile strength of the composite fabric have linear behavior before the failure point, and the maximum force 0.810KN, before a drop down happened incurring failure mode.

Table 6: Tensile test of recycled samples (two-layers)

Sample no	Force (KN)	Stress (MPa)	Elongation (%)	Modulus (MPa)
1	0.653	30.555	3.02	1894.798
2	0.596	20.977	4.78	374.819
3	1.181	32.078	3.83	1123.955
Average	0.810	27.870	3.87	1131.190

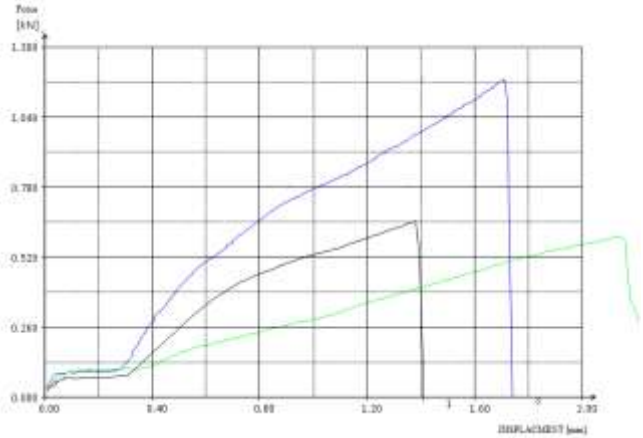

Fig. 4: *Tensile test of recycled samples (two-layers)*

4.1.5 Summary of tensile test:

Table 7 shows the summary of tensile test of sample (virgin and recycled).

Table 7: Summary of tensile test (Force N)

Sample	One-layer	Two-layers

Virgin	0.557 KN	0.964 KN
Recycled	0.282 KN	0.810 KN

From table 7 the force of virgin samples of one layer is 0.557KN and for recycled sample is 0.282KN (Decreased to 49% in compare to virgin). Also, a virgin sample of two layers is 0.964KN and for recycled sample is 0.810KN (Decreased to 16% in compare to virgin).

4.2 Bending test

4.2.1 Virgin samples (one-layer)

One-layer virgin sample was too flexible to give a result (no results)

4.2.2 Virgin samples (two- layers)

Table 8 and Fig 5 shows the results for bending test of virgin (two-layers) samples

Table 8: Bending test of virgin samples (two-layers)

Sample no	Force (kN)	Stress (MPa)	Modulus (MPa)
1	0.049	79.200	4395.530
2	0.048	74.557	-
3	0.044	79.682	-
Average	0.047	77.813	1969.266

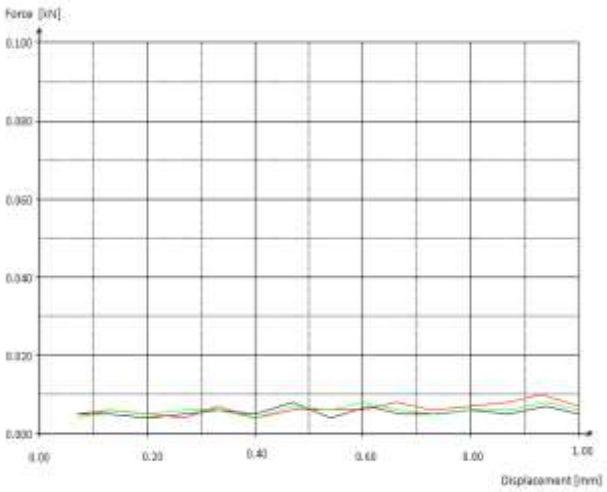

Fig. 5: *Bending test of virgin samples (two-layers)*

4.2.3 Recycled samples (one layer)

Table 9 and Fig 6 shows the results for bending test of recycled samples

Table 9: Bending test of recycled samples (one-layer)

Sample no	Force (kN)	Stress (MPa)	Modulus (MPa)
1	0.021	42.319	404.799
2	0.026	48.719	2586.208
3	0.022	55.378	1514.428
Average	0.023	48.805	1501.811

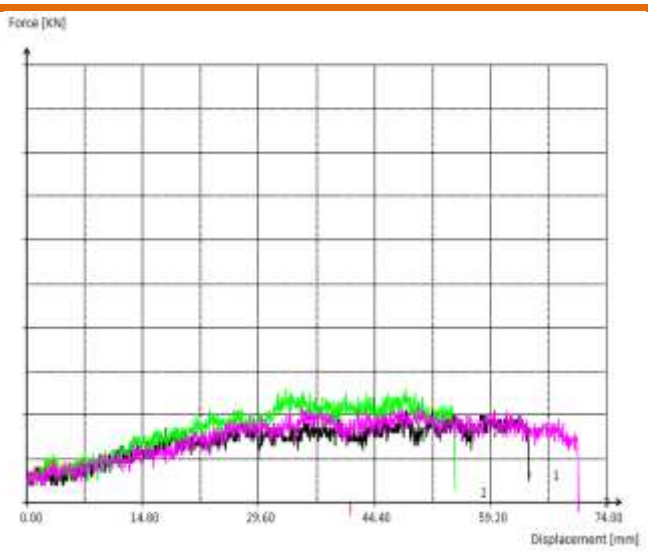

Fig. 6: *Bending test of recycled samples (one-layer)*

4.2.4 Recycled samples (two layers)

Table 10 and Fig 7 shows the results for bending test of recycled samples

Table 10: Bending test of recycled samples (two-layer)

Sample no	Force (kN)	Stress (MPa)	Modulus (MPa)
1	0.139	93.191	8010.291
2	0.090	65.286	6707.780
3	0.044	34.011	3827.518
Average	0.091	64.163	6181.863

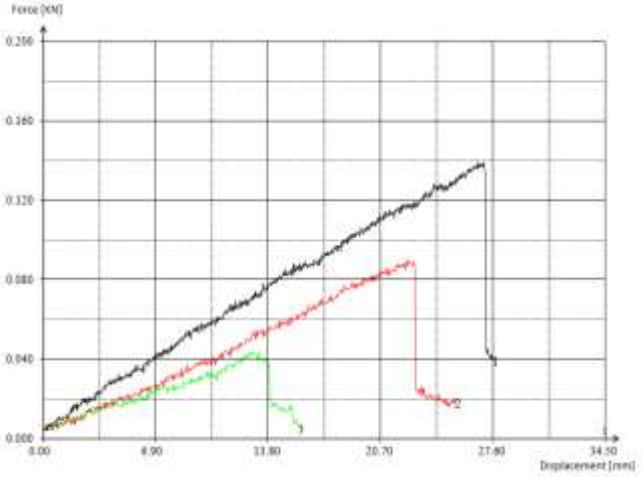

Fig. 7: *Bending test of the virgin samples*

4.2.5 Summary of bending test:

Table 11 shows the summary of tensile test of sample (virgin and recycled).

Table 11: Summary of tensile test (Force N)

Sample	One-layer	Two-layers
Virgin	-	0.047 KN
Recycled	0.023KN	0.091 KN

One-layer virgin sample was too flexible to give a result. But for two-layers recycled sample, the force increased compared to virgin.

4.3 Hardness test

4.3.1 Virgin samples

Table 12 show the results for hardness test of virgin samples

Table 12: Summary of virgin samples hardness test

Sample no	One-layer	Two-layers
1	91.0	94.0
2	91.5	95.0
3	92.0	95.0
Average	91.5	94.5

Table 13 show the results for hardness test of recycled samples

Table 13: Summary of recycled samples hardness test

Sample no	One-layer	Two-layers
1	90.5	90.5
2	91.0	94.0
3	91.5	98.0
Average	91.0	94.2

4.2.5 Summary of hardness test:

Table 14 show the summary of tensile test of sample (virgin and recycled).

Table 14: Summary of hardness test

Sample	One-layer	Two-layers
Virgin	91.5	94.5
Recycled	91.0	94.2

5. Conclusion

Mechanical properties of one and two layers of virgin and recycled glass fiber/polyester composite have been studied. Mechanical tests are applied such as tensile, bending and hardness test for evaluations the properties of varies samples. The results obtained the recycled glass fiber/polyester composite has low properties compare to virgin.

6. References

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