Recycling of Fiber Reinforced Plastic to Reuse it in Different Applications

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***Abstract*- In recent years, the introduction of plastic materials used in day to day life has been increased drastically. The production of fiber reinforced plastics (FRP) composite materials is a major source of non-degradable waste. Fiber reinforced plastics (FRP) materials are being increasingly used in several applications, but especially in the construction and transportation industries. The management of FRP materials, particularly those made with thermosetting resins, is a critical issue for the composites industry as these materials cannot be re-processed. This study focuses on recycling FRP chop waste. FRP is recycled by shredding it in small powdered sized particles and moulding it with suitable matrix like resin, concrete and fly ash. By this research huge amount of FRP waste can be reused and light weight but strong products can be manufactured. This paper presents a state-of-the-art solution for the present methods available to manage FRP waste. Thus results obtained from recycled FRP products are satisfying than the commercial plastics which is discussed. Different products made from waste reused FRP are gone under destructive testing like compressive strength, SEM for microstructure, shore testing for hardness, etc. For compressive strength universal testing machine (UTM) is used and results are discussed.**

Keywords*- *FRP, thermosetting resins, universal testing machine, Composites.

I. INTRODUCTION

In today's world situation demand for lightweight, strong and cheap materials is very high due to their higher strength to weight ratio. In such materials there are materials like plastics, fibers, composites, etc. as they are more robust and does not affect due to environment. In advance of this, there is a material called Glass Fiber Reinforced Plastics (GFRP) which is a composite material made from combination of fiber mats and plastic resin. Fibre-reinforced plastic (FRP) is a composite material fabricated by a polymer matrix reinforced with fibres. The fibres are generally glass, carbon, aramid or basalt and polymer is usually an epoxy, vinyl-ester or polyester thermosetting plastic; phenol formaldehyde resins are still in use. FRPs are commonly used in the domestic, aerospace, automotive, marine, and construction industries. Due to its advantages over other materials and plastics, there demand in today's world condition is increasing drastically because of its higher strength to weight ratio, light weight, higher strength, and it does not degrade due to environment. Fiber reinforced plastics (FRP) composite materials is a major source of non-degradable waste. Fiber reinforced plastics (FRP) materials are being increasingly used in several applications, but especially in the construction, aerospace and transportation industries. The industries are now manufacturing a wide variety of FRP products that include strengthening sheets, reinforcing bars, structures, sandwich panels, moulded planks and piping. Large amount of FRP waste is being produced in industries every day. So it is necessary to have a onetime solution over this issue by recycling it or by reusing it in different manner.

There are many ways to recycle or reuse FRP viz, chemical treatment, thermal treatment, etc. but this methods are time consuming and costly too. So the third method for reusing the FRP waste is by mechanical method. In mechanical method the FRP waste is chopper into small sized particles and then they can be moulded into different shapes according to the use by mixing it into matrix. For chopping FRP into smaller sized particles, different types of shredders or choppers can be used according to type of FRP waste and amount of FRP waste that should be chopped per hour.

The growing use of FRPs in the construction and transportation industries implies larger and increasing amounts of FRP waste, produced at different stages of their life cycle. The main concern is related to the limited solutions for the waste management of these non-reprocessable thermosetting FRPs.

II. Literature review

Adetiloye A. and Ephraim M. E. observed that, concrete beams, reinforced with GFRP based on recycled resin, shows good bonding but exhibit lower load carrying capacity in comparison with the metal reinforced concrete beams. The flexural strength of beam, reinforced with GFRP, used with recycled resin was about 400 percent higher than that of normal concrete beam. The flexural strength of GFRP reinforced beams increased with reinforcement ratio up to 4% reinforcement ratio beyond which substantial strength rise was not observed. The deflection of concrete beams reinforced with GFRP based on resin, is generally higher compared to those for the beam due to the low elastic modulus of the GFRP reinforcement. The failure mechanism of concrete beams, reinforced with GFRP based on resin, was slightly different compared with that of the normal beams. The GFRP reinforced concrete beams failed by concrete crushing at the compression zone of the GFRP reinforcement. The failure of GFRP reinforced concrete beams was firstly by ample warnings in the form of large deflections and crack developments similar to that observed in steel reinforced concrete beams.

Ardavan Yazdanbakhsh, and Lawrence C. Bank studied that, Landfilling FRP wastes is still the easiest and cheapest methods for managing FRP waste in most countries. However, environmental regulations are becoming tighter and it is expected that landfilling FRP will be more restricted, as it already is in several countries. The newly researched application of mechanically recycled FRP waste is its use as a partial replacement as fillers in new FRP composite materials. This usually enhances the mechanical properties of the new composite material. Replacement as aggregates in concrete and mortars is another potential application of mechanically recycled FRP. In most experiments on the mechanical properties of FRP waste incorporated with concrete and mortars, finely ground FRP particles have been used as with replacement of aggregates. Fine FRP waste particles consist of poor bonded pieces of polymer resin and fibers. Since polymer resins have a low stiffness, if the FRP waste has high resin content, it may reduce the strength of concrete or mortars. It was hypothesized that using larger sized FRP aggregates with rough surface will give a much smaller adverse effect on the mechanical properties of cementations materials.

Bhaskar Chandra Kandpal, Rakesh Chaurasia discussed about the type of green composites, processing of green composites and the research work going in the field of green composites. The focus is on enhancing the processing of green composites in more economical way as the raw material cost in green composites is very cheap. Researchers are using these green composites in various applications according to their use.

Eylem Asmatulu Janet Twomey and Michael Overcash suggested about fiber recovery which is the primary goal of most studies in this field. Among the three major types of composite recycling methods, chemical recycling provides the highest-strength fibers. Next provider of high-strength fibers is a mechanical recycling, followed by thermal technologies. It is clear that energy and economy analyses of composite recycling needs additional attention. As in most recycle–reuse industries, the next phase is development of recycling infrastructure, with cost sharing such as consumer fees with new products, State support for industry location and jobs, and expanded markets for recycled materials. Direct composite recycling may be an important approach for the composite and recycling industries. The study has shown that the composite products appear to have better value if they are recycled as composite structures rather than composite constituents. This also requires fewer resources, and less energy and labor to produce new hybrid products for various industries, such as construction, furniture, and automobile and other transportation, etc.

III. Materials and methods

Recycling of Glass Fiber Reinforced Plastics (GFRP) waste in manufacturing of building materials

A. Objectives of the experimental program

GFRP waste generated when cutting FRPs is constituted by very fine particles. Despite their high specific surface area the presence of low amounts of fine particles in paver blocks mixtures is known to have a positive influence on the workability and water resistivity of the mixture of material used for manufacturing of paver blocks, and to promote a filler effect and a reduction of porosity.. The experimental programmer was designed to investigate more thoroughly the technical feasibility of reusing filler-sized waste generated by cutting GFRP pieces in building materials production.

B. Materials used for manufacturing of paver blocks made by using GFRP waste

i. GFRP waste:

The GFRP waste used in this study (Fig. 1) was generated by the cutting waste produces due to removal of excess material from dies. Due to its small particle size and high silica content, which makes the cutting waste particularly hazardous to exposed workers and environment, cutting devices often incorporate a vacuum system that captures and stores the GFRP waste in bags.

Fig. 1 GFRP waste

ii. Matrix or thermosetting plastics:

Suitable resin can be used as a binding agent for joining shredded GFRP waste with aggregates so as to mould it in predesigned shape and increase its strength. Certain accelerator can be used to accelerate the hardening time of the matrix so as to increase the production rate of the production process.

iii. Aggregates:

Mixtures can be produced using coarse aggregate (CA) obtained from crushed limestone and two fine aggregates extracted from sedimentary deposits.

IV. Result and discussion

A. Sample fabrication

Different samples are fabricated for compression testing whose dimensions are 30mm×30mm×35mm

Table 1: Prototype specifications

Matrix- Polymer Resin			
Sr. No.	Powder (% wt.)	Catalyst (% wt.)	Matrix (% wt.)
Powder Size -5mm			
1	50%	5%	45%
2	60%		35%
3	70%		25%
Powder Size- 2mm			
4	50%	5%	45%
5	60%		35%
6	70%		25%
Powder Size- mixed (2mm+5mm)			
7	50%	5%	45%
8	60%		35%
9	70%		25%
Matrix- Concrete			
10	30% (2 mm)	10% (Aggregate)	60%
11	30% (5mm)		
12	30% (2mm+5mm)		
13	30%	10% (Aggregate) + 5% Metal Reinforcement	55%

B. Mechanical properties of fabricated prototypes

Table 2: Mechanical properties of fabricated prototypes

Specimen		Dimension (mm^3)	Mass (g)	Volume (mm^3)	Density (g/cm^3)	Relative density (-)
50 %	2mm	30×30×35	34.530	31500	1.0961	0.2736
	5mm		36.700		1.1650	0.2575
	Half cast (2mm+5 mm)		34.470		1.0942	0.2741
60 %	2mm		35.920		1.1403	0.2630
	5mm		36.810		1.1685	0.2567
	Half cast (2mm+5 mm)		34.870		1.1069	0.2710
70 %	2mm		36.260		1.1511	0.2606
	5mm		36.970		1.1736	0.2556
	Half cast (2mm+5 mm)		35.180		1.0022	0.2993
30 %	2mm		52.300		1.6603	1.3009
	5mm		51.810		1.6447	1.3133
	Half cast (2mm+5 mm)		49.770		1.5800	1.3670
	Metal reinforcement		55.360		1.7572	1.2292

C. Results from compressive strength and comparison with commercial polymers

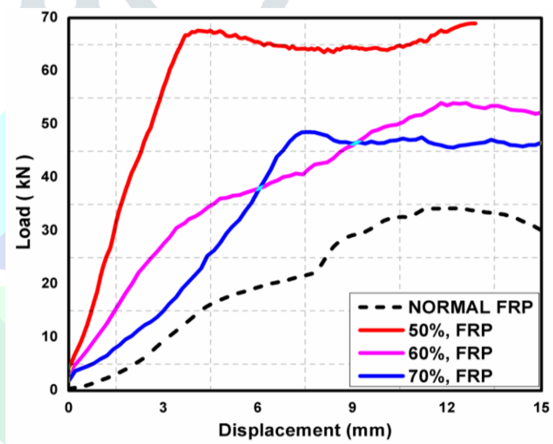

Fig 2(a): 2mm FRP waste powder

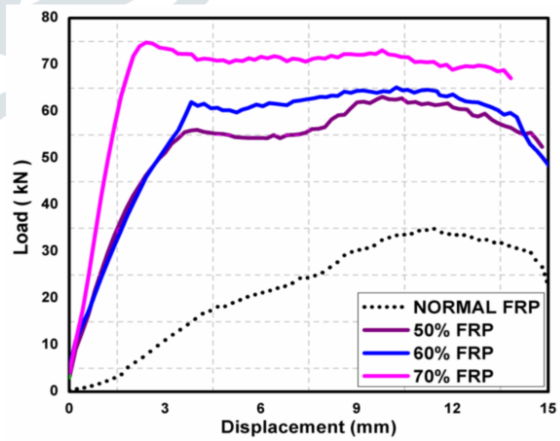

Fig 2(b): 5mm FRP waste powder

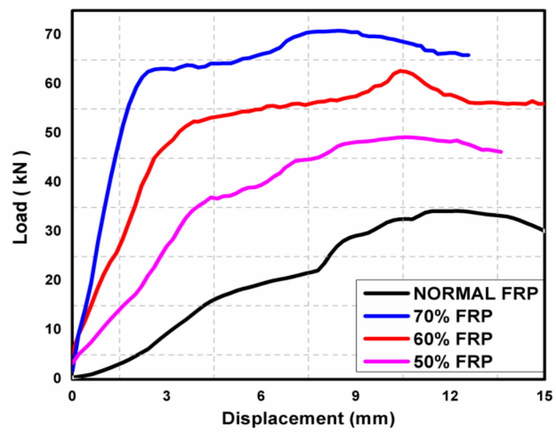

Fig 2(c): mixed FRP waste powder

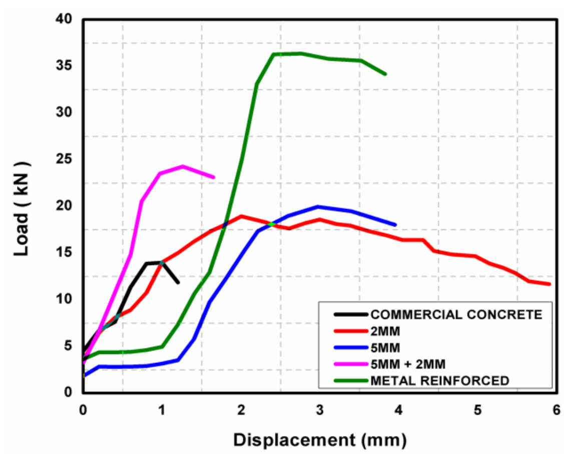

Fig 2(d): concrete with FRP waste powder

Figure 2 depicts load-displacement curves for (a) 2mm, (b) 5mm, (c) half cast (2mm+5mm) FRP powder sized samples fabricated using polymers polymer resin and concrete using varying powder percentage i.e. 50%, 60%, 70%, and strain rate applied (1s-1). (a) Compressive load-displacement diagram of the recycled and reused FRP with fiber length of 2mm with varying proportion of FRP waste powder (50%, 60% and 70% by volume) levels synthesized using polymer resin. It is observed that compressive strength of commercial FRP tested sample was 0.033kN/mm2 which is increased up to 0.077kN/mm2 with addition of FRP powder by 50%. (b) In fiber length of 5mm, it was found that compressive strength changes from 0.033kN/mm2 to 0.083kN/mm2 with addition of FRP powder by 70%. (c) In fiber length of half cast (2mm + 5mm), it was found that compressive strength changes from 0.033kN/mm2 to 0.079kN/mm2 with addition of FRP powder by 70%. (d): Compressive load-displacement diagram of the recycled and reused FRP with fiber length of 2mm, 5mm, half cast (2mm + 5mm) and metal reinforcement (50% by volume) synthesized using concrete. It is observed that compressive strength of commercial concrete was 0.016kN/mm2 which is increased up to 0.023kN/mm2 with addition of FRP powder by 50%. Also if concrete is reinforced with metal compressive strength increases to 0.040kN/mm2.

By observing the results we can conclude that increase in the fiber length also increases the strength of products. Addition of larger fiber length FRP in increasing percentage also increases the strength of products. Lesser the fiber length and higher the addition percentage lesser will be the strength and vice versa.

D. Microstructure testing of FRP waste powder

Fig 3(a): 2mm powder of FRP waste

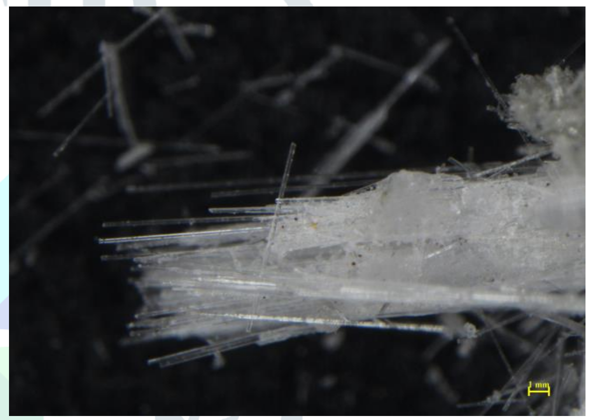

Fig 3(b): 5mm powder of FRP waste

Fig 3(c): mixed powder of FRP waste

V. Conclusions

Now day thermosetting FRP products are being increasingly used in several industrial applications. However, since they cannot be remelted or recycled most of the FRP waste is presently being sent to landfill and this disposal method increases harm to the environmental. Whole world is becoming more restrictive, thereby promoting the development of more sustainable recycling and reuse solutions. Some alternatives for the recycling of thermosetting composites are already in being used, but the FRP industry needs to develop additional sustainable solutions to cope with the increasing FRP waste production. The authors conducted experiments to ascertain the technical feasibility of incorporating the fine waste generated during the production of GFRP composites into different products. The following conclusions were drawn from this study:

1. Filler-size waste generated in the cutting of GFRP elements is fit for production of different products.

2. Addition of chopped FRP waste powder increases the strength of commercial polymers about 2 times.

4. Reuse of GFRPW in concrete is technically feasible for applications where compressive strength is not the main requirement, such as architectural concrete or pavement slabs. Results from other research works show that the incorporation of very fine particles may lead to the better performance of building materials.

References

[1] Adetiloye A, Ephraim M. E "Structural Engineering Properties of Fibre Reinforced Concrete Based On Recycled Glass Fibre Polymer (GFRP)" [Journal] // Int. Journal of Engineering Research and Applications . - 2015. - pp. 40-46.

[2] Ardavan Yazdanbakhsh, Lawrence C., Bank A "Critical Review of Research on Reuse of Mechanically Recycled FRP Production and End-of-Life Waste for Construction" [Journal] // polymers . - 2014.

[3] Bhaskar Chandra Kandpal, Rakesh Chaurasia "Recent Advances in Green Composites" [Journal] // International Journal For Technological Research In Engineering. - 2015.

[4] Eylem Asmatulu Janet Twomey and Michael Overcash "Recycling of fiber-reinforced composites and direct structural composite recycling concept" [Journal] // JOURNAL OF COMPOSITE MATERIALS. - 2013.

[5] Richard P. Turner, Catherine A. Kelly "Re-Formative Polymer Composites from Plastic Waste" [Journal] // recycling. - 2018.

[6] Soraia Pimenta Silvestre T. Pinho "Recycling carbon fibre reinforced polymers" 2011.