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Mechanical Properties of Waste Plastic Reinforced Epoxy Matrix Composites

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Abstract:** Management and treatment of plastic waste can mitigate adverse impacts on environment process and human health. The aim of the present study was to develop and characterise polymeric composite waste plastic pellets by means of hand lay-up process techniques. The new materials will be used for manufacturing floor tiles that are environmentally friendly, light but still technically qualified, and are expected to replace the ceramic tiles that are relatively heavy. The recycled plastic are converted into small sized pellets forms by pelletizing process. Plastic resin pellets are small granules generally with shape of a cylinder or a disk with a diameter of a few mm. These waste plastic pellets and teak wood fine powder are particles of the composite, which its improving the mechanical properties of laminated composites. This paper presents an overview of the mechanical properties and durability of recycled mixed plastic waste composites. Several composite materials were prepared by changing a composition along with 10%, 20%, 30% and 40% of recycled pellets aggregate.
Keywords: Recycled plastic wastes, wood powder, wood-plastic composites.

I. INTRODUCTION

Wood filler is increasingly used for reinforcement in thermoplastics due to their low density, good thermal insulation and mechanical properties, unlimited availability, and low price. The rapid expansion of wood plastic composite (WPC) production raises serious concerns about a shortage of lingo cellulosic material to support the industry's needs. There is interest worldwide in the development of intensively managed fast-growing wood species for WPC production. The use of fast-growing wood species may be an alternative way to not only extend the industry's wood supply, but also to preserve natural resources from over-exploitation.

According to statistics, the biggest plastic waste outlets in Europe, e.g. in the UK, are commercial and household packaging, approx. 58% of total plastic waste, followed by the building and construction sector, approx. 10% [7]. Construction plastic waste can contain packaging as well as non-packagingmaterial, i.e. insulations, pipes, ducts and others.

In the European Union, of the 25 Mt of plastic waste generated in 2008, 12.1 Mt (48.7%) was landfilled, while 12.8 Mt (51.3%) went to recovery, and only 5.3 Mt (21.3%) was recycled [2]. The main obstacle for more effective recycling of post-consumer plastic waste is its heterogeneity. In the plastic waste stream, low-density polyethylene (LDPE) and linear lowdensity polyethylene are the largest components, followed by high-density polyethylene (HDPE), polypropylene (PP), polystyrene, polyvinyl chloride (PVC), polyethylene terephthalate, as well as other types of plastics.

To make things worse, millions of tonnes of this waste end up in the oceans. Birds, turtles and sea life get tangled in plastic bags and abandoned fishing equipment, or they die from eating plastic debris. Over time, larger pieces of plastic break down into tiny particles called micro plastic, which can form a sort of plastic soup. These particles can soak up chemical additives and endocrine disruptors, and when they are eaten and enter the food chain, they can end up on our plates. It's a large-scale problem, and it needs a global response.

Plastic recycling is an important tool in environ mentally friendly waste management because of the large amount of polymers used in many applications. Many plastic articles, in particular packaging, containers and other items, have a short life leading to waste materials that are slightly degraded and then with properties similar to those of the virgin materials. The melt reprocessing, necessary in the recycling operations of many polymers, can induce thermo mechanical degradation and then worsening of mechanical properties, aesthetic appearances, etc.

Recycled plastic pellets are essentially the middle line between waste plastic and the manufacturing of finished goods. Creating recycled plastic pellets is usually the final step in the recycling process before the material is distributed for the industrial production stage. Recycled plastic pellets are therefore one of the more popular choices for manufacturers.

Once waste plastic has been put through a plastic grinder and broken down, the smaller pieces are melted and compressed into

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recycled plastic pellets. These final recycled plastic pellets from RVK Enterprise are a high grade of enhanced, recycled material that is ready for remanufacturing.The utilization of recycled plastic for the manufacture of recycled plastic pellet and wood particulate composites (WRPCs) has been studied by a number of authors [3, 4].Composites containing recycled plastics and wood sawdust particles offer interesting combinations of properties [5–7]. This result is a strong impetus to expand the use of recycled plastics in the manufacture of WRPCs. The use of recycled plastic and wood sawdust seems inevitable, and the present opportunities are promising [9].

Comparisons of the stiffness/weight efficiencies revealed that the stiffness of wood composites equals or exceeds that of most traditional materials of construction, including steel, aluminum, glass-fiber composites, and talc-filled polyolefin, while retaining a major material cost advantage [10]. However, a major issue in achieving true reinforcement for teak wood-recycled plastic composites is the inherent in compatibility between the hydrophilic fibers and the hydrophobic polymers, which results in poor adhesion and, therefore, in poor ability to transfer stress from the matrix to the reinforcing fibers [11]. A more promising way to recover the economic value of this mixture could be the manufacturing of plastics lumber combining cellulosic reinforcement by blending techniques without separation. Cellulose materials offer several advantages, when combined with plastics, because of their low density, high modulus, and high strength.

In this work, we report on the effect of combining teak wood sawdust powder and recycled plastic materials on the mechanical properties of the recycled plastic reinforced composites. The composites are analyzed on a wide range of mechanical properties (flexural, tensile, impact and hardness), and their wettability. In addition, the thermal properties are studied with differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) techniques. Scan electron microscopy (SEM) is used for monitoring composite morphology.

II. MATERIALS AND METHODS

A. Materials

The matrix material used in the fabrication of composite material was a mixture of Araldite epoxy resin (LY556) and hardener (HY951) mixed thoroughly in mass ratio (10:1).Two different fillers, namely recycled plastic pellets and teak wood powder of average sizes ranges from 75 - 105 mm were used as particulate reinforcements. The fillers were added in different mass percentages of matrix of epoxy resin to obtain different levels of reinforcement.

The wood fibers were collected from wood sawdust in the woodshop, the main species of which were hardwoods with an apparent density of 0.2–0.3 g/cm3. Fibers were separated by sifting into different mesh particle sizes. For the 48–100 mesh, the average wood fiber length was 225 lm, and the fibers were dried in an oven at 150ºC for 2 hrs to ensure that their moisture content was less than 3%.

B. Processing of fillers

The fillers were obtained by grinding the respective raw materials to fine powders of size ranging in microns using a grinding machine. The grinding process increased surface roughness and contact area of the fillers, which favored mechanical interlocking with the matrix.

C. Mould preparation

Mould was fabricated with a mallex sheet of 50×50 cm size and rubber block piece was pasted on the dimensions of 300 mm × 300 mm on four sides. The fabrication was carried out through the hand lay-up technique. Before lay-up process the mould has been applied with a releasing agent to insure that the art will not adhere to the mould .The top and bottom plates are covered with mallex sheet and the fibers, using epoxy resin compressed to avoid the debris from entering into composite parts during curing.

D. Preparation of particulate filler composites

The hardener HY951 was added into the epoxy resin LY556 in mass ratio 1:10 and stirred well. Dried filler in different mass percentages of resin as required was mixed with the epoxy-hardener mixture. The mixture was stirred thoroughly for 8 - 10 minutes to form a homogenous suspension. Composite material was produced by pouring the resin filler mixture into a mould and curing at room temperature for 24 hours. Details of different combinations of composite materials are presented in Table 2.

To form laminated composites with three layers of lamina of glass fiber woven mats. The entrapped air bubbles (if any) are removed carefully with a sliding roller and the mould was closed for curing at a temperature of 30°C for 24 h at a constant load of 10 kg.

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Table: Various combination of two different fillers particles reinforced composites.

Samples	Recycled plastic waste particle content in gms	Teak wood powder in gms	Epoxy resin + hardener in gms
I	0	80	220
II	20	60	220
III	40	40	220
IV	60	20	220
V	80	0	220

After curing, the composites are extracted from the mould plate. Fabricated samples are placed in dry place for improving solid gel strength of the samples. Again repeat the same process for all samples preparation of hybrid natural composites.

E. Mechanical Testing

Tensile strength, tensile modulus was measured using Universal Testing Machine - UTM (Instron 5567). Tensile test specimen were made according to ASTM D 638M. A crosshead speed of 5 mm/min was used. All specimens were conditioned at a room temperature before testing. Hardness test specimen was made according to ASTM D618. Impact test specimen was made according to ASTM D5628.

III. RESULTS AND DISCUSSION

The bonding at the fiber matrix interface plays a major role in the mechanical behavior of composite materials. In polymer matrix composites the most important function of the matrix is to distribute the applied stress among the fibers. The applied stress must be transferred across the fiber/matrix interface, transverse, longitudinal, shear strength of a polymer matrix composite depend heavily on the interfacial bond strength. Thus bonding must be maximized if the full strength of reinforcing fiber is to be realized, making accurate characterization of interfacial bonding in composite materials.

A. Effect of wood flour on tensile properties

The effects of the wood flour (WF), 54 wt%, on the tensile properties of the composites are shown in Fig.3. As can be seen, the samples injection-molded from polymer blends (PBs) had higher strength and stiffness compared to the sample produced from the commercial LDPE. The loading of wood flour influenced the properties of the reference sample, both tensile strength (TS) and tensile modulus (TM), positively.

Fig.1 various combinations of two different fillers particles reinforced composites.

B. Tensile test

The mechanical behavior of the composites prepared with the fabricated samples was tested in the Universal Tensile testing machine with testing load range of maximum 5 Ton with gear rotation speed of 1.25,1.5,2.5 mm/min. The experiments were conducted at normal room temperature .The test specimens were cut as per ASTM standards using cutting machining. The tensile strength was determined as per ASTM D 638 with standard gauge length of 50mm, with a cross head seed of 1.25 mm/min.

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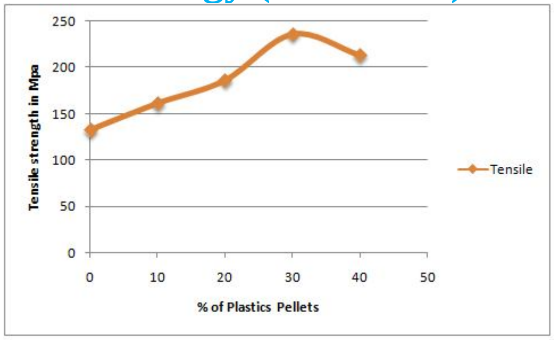

Fig: 2 Variation of tensile strength for different plastic pellets percentage.

Thus wood sawdust particles increases exposed on the bonding of the recycled plastic pellets surface resulting in better mechanical interlocking and epoxy resin matrix interfacial bond and, resulting in increased mechanical properties. Besides, the increase in tensile strength up to 30% fiber content is due to adequate adding of the pellets by the matrix and reasonable amount of plastic pellets to bear applied load. The decrease in strength and modulus at pellets content, of 40% probably resulted from poor bonding strength, also the epoxy resin content is not sufficient to wet all the plastic particle surfaces, leading to poor interfacial adhesion [13].

C. Impact Tests

Impact strength of the composite specimens was carried out in impact testing machine according to ASTM D 256 standard. The specimen size was 65.5*12.7*3 mm with depth under notch of 2.5mm .The izod impact test, is a standardized high strain rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent ductile-brittle transition.

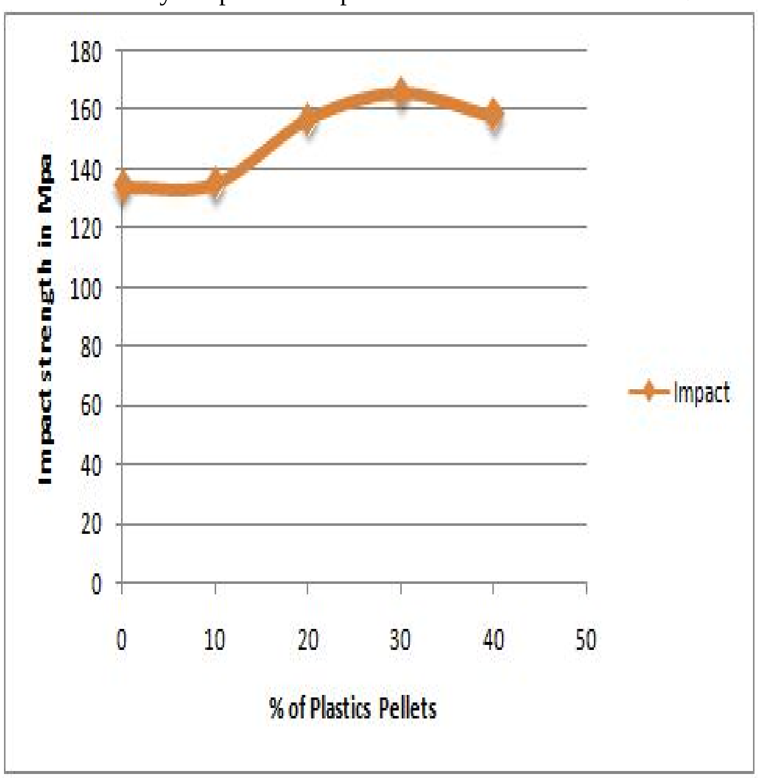

Fig: 3 Variation of impact strength for different plastic pellets percentage.

D. Hardness Test

The hardness is measured from an indentation produced in the composite by applying a constant load on a specific indenter in

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contact with the surface of the composite for fixed time. This test was carried out in hardness testing machine as per standard ASTM D 2240. Fig 4 shows that highest hardness strength was obtained from pure matrix materials when compared to pellets mixed matrix composites.

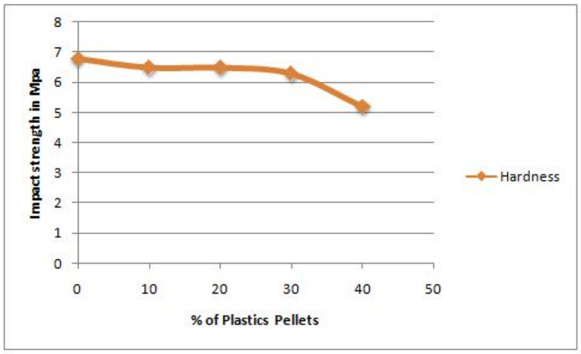

Fig: 4 Variation of hardness strength for different plastic pellets percentage.

IV. CONCLUSION

The mechanical properties of recycled plastic pellets and teak wood saw dust particulate composite have been investigated in this research. The results obtained reveal that the highest tensile and impact strength was obtained at 30% of plastic waste pellets particle content and highest hardness strength was obtained from pure matrix materials when compared to pellets mixed matrix composites.Besides, the increase in tensile strength up to 30% fiber content is due to adequate adding of the pellets by the matrix and reasonable amount of plastic pellets to bear applied load. The decrease in strength and modulus at pellets content, of 40% probably resulted from poor bonding strength, also the epoxy resin content is not sufficient to wet all the plastic particle surfaces, leading to poor interfacial adhesionIt was shown that wood fibers were very effective in the improvement of composite modulus, and the stiffness of the composites from secondary material was significantly higher compared to the reference; the hardness was comparable with the reference.

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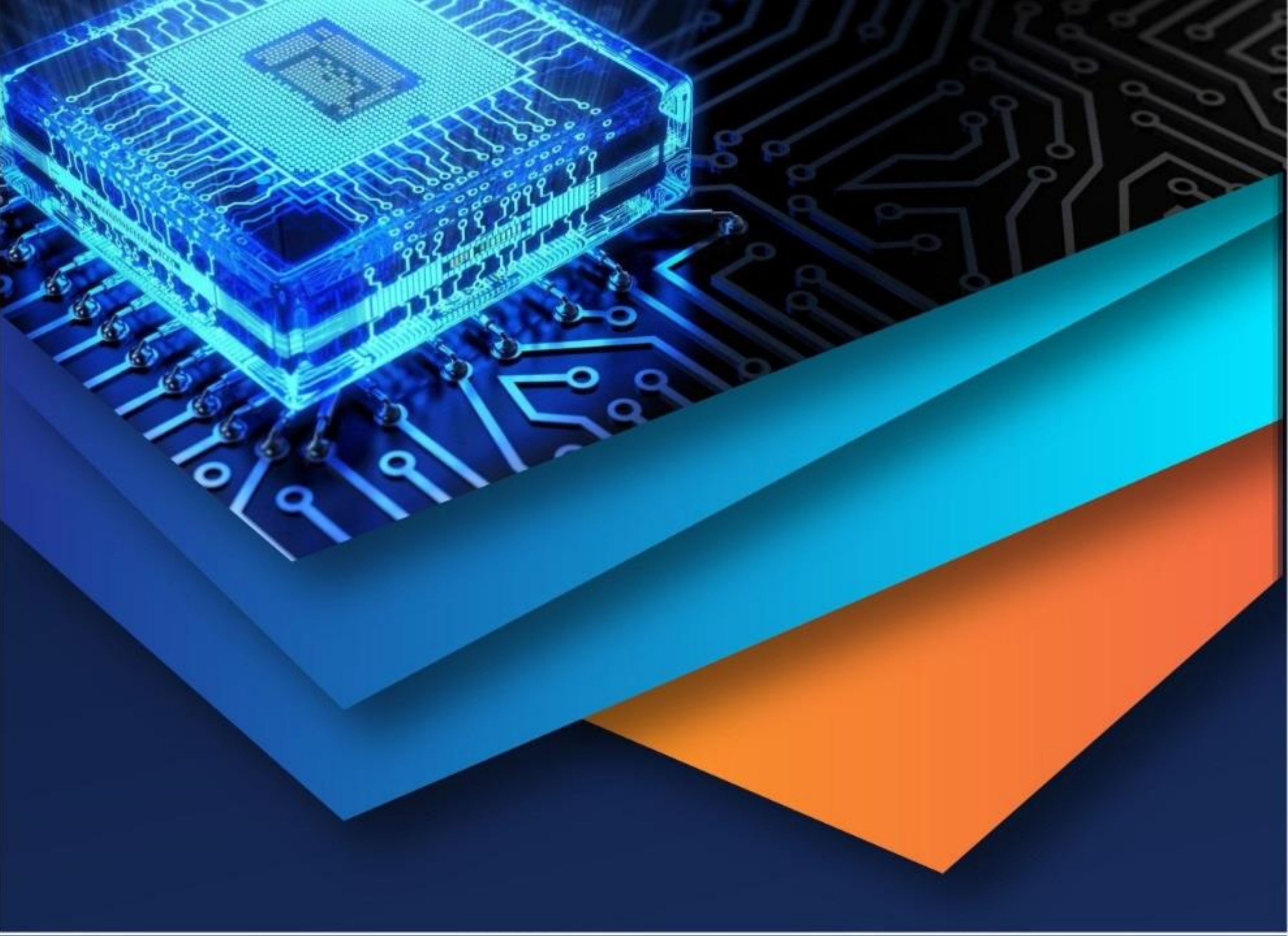

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