APPLICATIONS OF POLYMER REINFORCED COMPOSITES IN BUILDING MATERIALS

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ABSTRACT. In the present paper, the authors have highlighted the use of natural fibre graft copolymers as reinforcing materials for the preparation of composite materials. Natural fibre backbones used were Flax, *Saccharum spontaneous* L, mercerized Flax etc. Different vinyl monomers were graft copolymerized onto natural fibre backbones. Composites prepared were evaluated for different types of mechanical properties like tensile strength, compressive strength, modulus of rupture, modulus of elasticity, and stress at the limit of proportionality. The reinforcing graft copolymers were further evaluated for thermal stability. Other physico-chemical properties of the reinforcing agents were also studied. Reinforcing material Flax-g-poly(MMA/AA) has been found to exhibit better thermal stability compared to natural backbones. Phenol-formaldehyde composites reinforced with graft copolymers of Flax fiber showed excellent mechanical strength and can be used as a reinforcing material in cement to enhance its mechanical properties. Graft copolymerization of methylmethacrylate (MMA) onto the mercerized Flax (MFx) resulted in the formation of MFx-g-poly(MMA) graft copolymer which was reinforced onto polystyrene matrix. The composites prepared exhibited better mechanical properties and can be used as superplasticizers to overcome the fatigue and lower tensile strength of usual concreate material for infrastructure designing. MMA based graft copolymers of *Saccharum spontaneum L.* possessed very high moisture resistance ability and can be applied as a reinforcement material for designing moisture resistant infrastructures. The use of graft copolymers has been proved as forefront technology for designing 'Smart Building Materials' in future.

Keywords: Concrete, superplasticizers, graft copolymers

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INTRODUCTION

With the development of Material Science and Technology, many new materials are being discovered to overcome the problem of deteriorating infrastructure. The applications of Polymer Reinforced Concrete and other composites have provided a new revolution in the field of Civil Engineering to overcome the limitations of usual building materials like low tensile strength, high cycle fatigue, low thermal stability and shorter life spam [1]. Nowadays, graft copolymers are being used as superplasticizers to increase dispensability, fluidity and fluid-retaining performance of cement. These reinforcing agents are also used in the preparation of various types of Engineering Composites.

Newly designed construction materials of fiber reinforced polymers have high strength, non-corrosive properties and are lightweight materials [2]. Compared to conventional construction materials, fiber reinforced polymers have certain advantages:

- Low cost
- Flexibility of the material for installation purpose
- Control over the mechanical properties using appropriative choice of fibers
- High strength to weight ratios and low thermal conductivity
- Applicability in magnetic imaging facilities due to the electromagnetic neutrality of the material

Fiber reinforced composites provide better tensile strength and mechanical stiffness to the construction material. Thermal stability of the composites can be increased through the choice of reinforcing material. Recently, fiber reinforced composite materials have been considered for structural load bearing applications and these are used as a replacement material for the steal in reinforced concreate and civil structures. In a survey carried out during 1990, the civil and construction sector was found to consume 35% of polymer composites in global market [3]. Therefore, the discovery of new fiber reinforced composite materials is very important to meet out the traditional drawbacks of newly designed construction materials.

APPLICATIONS OF POLYMER REINFORCED COMPOSITES

Polymer reinforced composites provide dimensional stability and tensile strength to the construction material. Thermal stability and the electrical conductivity of the materials can also be controlled through the choice of reinforcing material. Polymer reinforced composites can be used in civil engineering for constructing buildings, bridges, houses, smokestacks, lampposts, and highway culverts [4]. Fiber reinforced polymer composites have been used for maintaining and strengthening of the existing infrastructure [5]. Aramid fiber reinforced composites have low density, excellent tensile fatigue properties and high specific strength with good specific modulus. Such types of reinforced composites are used in aerospace field, electrical and electronic related field, civil construction, ship building industry and sports market. In civil construction field, they are used as corrosion resistive, non-conductive and non-magnetic materials to replace steal bar and to construct curtain wall and reinforced bridge [6].

Graft Copolymers

Graft copolymers are the branched copolymers with a linear backbone of one monomer and randomly distributed branches of another monomer. A wide range of functional groups which can be more important from technological point of view can be inserted into the polymeric chain to form graft copolymer. The joining forces can be ionic interactions, hydrogen bonding and coordination-type interactions [7-9]. Later, covalent bonding was also generated to crosslink the chains. The primary purpose of the crosslinking functional groups was to modify the rheology and mechanical strength of the polymer. The joining functional groups were found to improve the physical properties of the graft copolymers [10-11].

Graft Copolymer Reinforced Composites

The term 'Composite' referred to a material made up of matrix phase and a reinforcing agent. The reinforcing agent of the composite provides stiffness, strength and stability to carry a load. Wood is a well-known example of natural composite 'cellulose fibers' dispersed in the matrix of lignin. Due to high strength to weight ratio, graft copolymer reinforced composites possess several applications in manufacturing technology [12]. Chouhal *et.al.,* has synthesized novel Roselle grafted fiber reinforced bio-composites using cerium ion initiator. The reinforced composite showed excellent mechanical strength and can be used in transportation, aerospace and packaging applications [13]. Sorrel stem fibers are rich in cellulose content and have high tensile strength. The low molecular weight of the fiber makes them suitable for graft copolymerization reactions. *Hibiscus sabdariffa* fiber graft copolymerized with ethyl acetate and its binary vinyl monomeric mixture modified the physico-chemical and thermal properties of the fiber. After the reinforcement of graft copolymers with phenoplast, the physico-chemico-mechanical strength increases which make them suitable for better scientific application for the advancement of technology [14]. Kaur *et. al.,* has evaluated the physico-chemical and thermal properties of graft copolymers based on soy protein and different binary mixtures of ethylacrylate (EA), methylacrylate (MA), methylmethacrylate (MMA) and ethylmethacrylate (EMA). The graft copolymers were found to be thermally more stable and showed moisture retardation properties [15]. Sereni Fiber Reinforced Composite showed excellent mechanical strength and good hydrophobicity [16]. Singha *et. al.,* synthesized and characterized *cannabis indica* fiber reinforced composites using Urea-Resourcinol-Formaldehyde matrix through compression molding technique. The composite fiber possessed excellent tensile strength, compressive strength, flexural strength and wear resistance strength [17]. Microwave radiations offer a new technique to graft copolymerize the vinyl monomers onto natural fibers. *Maiti et. al.,* have grafted methylmethacrylate (MMA) + acrylamide (AAm), MMA + acrylic acid (AA) and MMA + acrylonitrile (AN) onto *Saccharum spontaneum* L. Maximum graft yield of the sample was found to be 94.5% with MMA + AAm binary mixture. Graft copolymers were found to be more resistant towards moisture and chemicals [18].

Mechanical properties of graft copolymer reinforced composites

Graft copolymer reinforced composites exhibit excellent mechanical properties. The mechanical properties of some of the graft copolymer reinforced composite has been described in Table 1[14-18]. The grafted reinforced composites showed higher value of modulus of rupture, modulus of elasticity, hardness and stress at the limit of proportionality compared to non-grafted fiber. These mechanical properties of reinforced composite polymers make them suitable for the application as building materials for construction purpose.

Table 1: Mechanical properties of some graft copolymer reinforced composites [14-18]

SAMPLE CODE	STRENGTH TEST			
	Modulus of rupture (Nmm^{-2})	Modulus of elasticity (Nmm^{-2})	Stress at the limit of proportionality (Nmm^{-2})	Hardness
Phenol-formaldehyde	43.20	496.12	38.40	Brittle
H. sabdariffa-r-PF	69.99	614.40	57.60	67.00
Hs-g-poly(EA)-r-PF	82.04	898.56	74.24	75.00
Hs-g-poly(EA-co-MMA)-r-PF	78.00	680.00	70.00	78.00
Hs-g-poly(EA-co-BA)-r-PF	79.90	875.99	74.08	74.00
Hs-g-poly(EA-co-VA)-r-PF	71.96	689.80	60.56	70.00
Hs-g-poly(BA)-r-PF	75.16	720.60	66.00	70.00
Hs-g-poly(BA-co-AM)-r-PF	72.00	642.00	59.00	69.00
Hs-g-poly(BA-co-AA)-r-PF	73.00	780.00	60.00	68.00
Hs-g-poly(BA-co-4VP)-r-PF	73.00	690.90	61.00	70.00
PF matrix	60.0	2611.2	48.9	Not studied
Original flax reinforcement	77.76	3404.8	63.84	Not studied
Flax-g-poly(MA) reinforcement	112.8	5248.0	98.4	Not studied

Where, Hs = *Hibiscus sabdariffa* fiber, PF = phenolformaldehyde, EA = ethylacrylate, MMA = methylmethacrylate, BA = butyl acrylate, VA = vinyl acetate, AM = acrylamide, AA = acrylic acid, 4VP = 4-vinyl pyridine

The tensile strength and compressive strength of some of the graft copolymer reinforced composites is depicted in Table 2. *Hibiscus sabdariffa* particle reinforced Urea-formaldehyde composites was found to possess high tensile strength (332·8 N at an extension of 2·2 mm) and compressive strength (2586·5 N with a compression of 3·51 mm). All the polymer reinforced composites have sufficient tensile strength and compressive strength and thus, can be used during the construction of buildings [19-22].

Table 2: Comparison of the tensile strength and compressive strength of some graft copolymer reinforced composites [19-22]

SAMPLE CODE	TENSILE STRENGTH	COMPRESSIVE STRENGTH
Urea-formaldehyde matrix reinforced with Hibiscus sabdariffa particle	332·8 N	2586·5 N
Urea-formaldehyde matrix reinforced with Hibiscus sabdariffa Short fibre	307·6 N	2466·5 N
Urea-formaldehyde matrix reinforced with Hibiscus sabdariffa long fibre	286·1 N	2376·5 N
Raw Flex reinforcement of Phenol-Formaldehyde	150N	400N
Flax-g-poly(MMA) Reinforcement of Phenol-Formaldehyde	175N	800N
Phenol-Formaldehyde (PF) matrix	125N	212N
Original flax reinforced PF composites	162N	372N
Flax-g-poly(MA) reinforced PF composites	235N	814N
Flax-gpoly(MMA+VA) Reinforced PF Composites	75N	1000N
Flax-gpoly(MMA+AAm) Reinforced PF Composites	50N	700N
Flax-gpoly(MMA+Sty) Reinforced PF Composites	35N	400N

Chemical resistivity of graft copolymer reinforced composites

Applicability of the construction material used in chemical industry is decided by the resistivity of the material against chemicals. The chemical resistivity of the studied polymer composite fabrics is depicted in Table 3. It was observed that the grafted composites either degrade with very slow degradation rate or they do not degrade under acidic or basic conditions. This showed the chemical inertness of the graft copolymer reinforced composites and their applicability for designing chemically inert infrastructure [14-18].

Table 3: Chemical resistivity of some graft copolymer reinforced composites in 1N HCl and 1N NaOH solution [14-18]

GRAFT COPOLYMER	% CHEMICAL RESISTANCE (% WEIGHT LOSS) AFTER 72 HRS	
	1N HCl	IN NaOH
Hibiscus sabdariffa	45 (55)	57 (43)
Hs-g-poly-(BA)	63 (37)	74 (26)
Hs-g-poly-(BA-co-MA)	71 (29)	75 (25)
Hs-g-poly-(BA-co-VA)	88 (12)	92 (8)
Hs-g-poly-(EA)	100 (0)	100 (0)
Hs-g-poly-(EA-co-MMA)	100 (0)	100 (0)
Hs-r-PF-composite	99 (1)	100 (0)
Hs-g-poly-(EA-co-BA)	96 (4)	100 (0)
Hs-g-poly-(EA-co-VA)	60 (40)	70 (30)

Where, Hs = *Hibiscus sabdariffa* fiber, BA = butyl acrylate, MA = methylacrylate, EA = ethylacrylate, MMA = methylmethacrylate, VA = vinyl acetate

Thermal stability of the graft copolymer reinforced materials

The graft copolymers were found to be thermally more stable as compare to the non-grafted backbones. *S. spontaneum* showed two-stage decomposition of the material in the temperature range from 225-320°C with 60% weight loss and 320–416°C with 25.33% weight loss. The graft copolymers of S. spontaneum Ss-g-poly(MMA+AAm), Ss-g-poly(MMA+AN) and Ss-g-poly(MMA+AA) were found to show single stage decomposition with initial decomposition temperature = 251°C, 250°C and 250°C, respectively. The % weight loss at the final decomposition temperature was found to be 78.51% (FDT = 555 °C), 84.83% (FDT = 550 °C) and 81.49% (FDT = 502 °C) for Ss-g-poly(MMA+AAm), Ss-g-poly(MMA+AN) and Ss-g-poly(MMA+AA), respectively. The higher FDT of graft copolymers suggested high thermal stability of the samples compared to non-grafted fiber [23]. Polymer reinforced composites exhibit excellent thermal stability which makes them important material to be used in civil engineering for construction purpose [24].

CONCLUSION

Graft copolymer reinforced composites showed excellent mechanical properties such as modulus of elasticity, modulus of rupture, stress at the limit of proportionality and hardness. These composites also showed sufficient thermal stability along with chemical resistivity.

Thus, these materials can be used as reinforcing materials for construction purpose in civil engineering. The mechanical strength, water resistivity and chemical resistivity of polymer reinforced composites can be controlled through the extent of grafted monomeric chains. Thus, polymer reinforced composites can be used for different applications through the control over mechanical strength and degree of grafting.

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