Effects of Additives and Treatment on Fly Ash-Based Polymer Composites

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1 Introduction

Fly ash which is also called fuel ash is result of burning of coal used in thermal power plants for the generation of electrical energy. In modern era, thermal power plants are mostly operated on burning of coal and the resulted fly ash is captured with the help of electrostatic precipitators or other equipment such as particle filtration. The coal is extracted from various parts of land not from one particular part; therefore, its composition varies depending upon the place from where it is extracted. But all types of coal contain some amount of silicon dioxide, aluminium oxide and calcium oxide which all are found in fly ash when the coal is burned. In early days when coal was first used power plants, fly ash that was produced was dumped into land near the power plants. In the beginning, people did not noticed that it was harmful to humans as well as environment. But when it was noticed, various laws were passed to contain the unsafe dumping of fly ash. It was advised to use various equipment which were helpful in pollution control. Therefore, disposal and utilization of fly ash is a major issue observed by academicians and researchers. Reinforcement in various polymer matrix to form composites is an option which can give a new way of sustainable development and diversity of applications in the field of material science and composites. Nowadays, concrete is mostly used in construction works, and binding material is mainly cement. But using cement is also a problem because it results in emission of 8% of global carbon dioxide. Therefore, many studies suggest that if we use geopolymer concrete than normal concrete, than it can lower the emission of carbon dioxide as its binding material consists fly ash [1]. Due to this reason, almost 15% of fly ash produced in India is used to manufacture the concrete. In

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year 2012–2013 in India, 163.56 million tone of fly ash was generated in comparison with year 1996–1997 in which 68.88 million tone was generated, out of which 63.17% of ash was utilized [2]. Composition of fly ash varies in different ways as bituminous fly ash contains SiO_2 (20–60%), Al_2O_3 (5–35%), Fe_2O_3 (10–40%), CaO (1–12%), Lol (0–15%). Similarly subbituminous fly ash contains silica oxide (40–60%), Al_2O_3 (20–30%), Fe_2O_3 (4–10%), CaO (5–30%), Lol (0–3%), and lignite fly ash contains SiO_2 (15–45%), Al_2O_3 (20–25%), Fe_2O_3 (4–15%), CaO (15–40%), Lol (0–5%) [3]. Fly ash can also be used for making bricks. Normally clay is used to make bricks, but if used fly ash, then it can help in removing fly ash from open grounds or dumpsters. As dumping of fly ash also results in ground pollution. If we use 25% fly ash in making bricks, it can help in reduction of weight by 18%, but it will not affect the strength of bricks [4]. Utilization of fly ash in geopolymer composites increases its strength, but if it is exposed to sulphuric acid, then it does not helps much but if we use some amount of OPC in it, then it can further increase its strength. Because OPC can resist sulphuric acid greatly [5].

2 Fly Ash Composites

A composite is a material which is formed by combining two or more materials having separate physical and chemical properties. When the two materials are mixed, it is done with the purpose of creating a material to complete a specific task, such as to make a material stronger than usual, or lighter or immune to electric currents. Most of the composite materials are mixture of two materials only. One of which is the matrix or also known as binder. Purpose of the binder is to bind or surround the fibres or particles of other material. The other material is called reinforcement. The first composite material formed in modern time was fibreglass. There are various reasons to use composite materials. One of the main reasons to use composite materials is because of its unique properties such as its ability to save its weight in relative stiffness and strength. Reinforcement of fly ash in polymer matrix can not only serve the purpose of its disposal and at the same time can provide distinct properties as compared to individual phase. These polymer matrix may be thermoset or thermo polymer depending on the requirement of application. Some widely used polymer matrix in which reinforcement of fly ash has been applied is discussed below.

2.1 HDPE Based Composites

HDPE is the most common and important thermoplastic product made from petroleum, and it is in high demands in recent times due to its high strength, toughness, cost-effective nature; less permeable to moisture and other oxidizing agents; fine elongation property; and its ability to remain unaffected for surface impacts. It can also be used for various applications such as packaging or other commercial

purposes. If we melt down fly ash and mix with HDPE, it will increase its flexural property [6]. If we further study three other methods to study the impact fly ash composites such as Maleic Anhydride grafting method of matrix, electron beam irradiation method and irradiation method of fly ash/ nano-fly ash separately then out of these three methods we will find that electron beam irradiation of HDPE–fly ash/nano-fly ash results in tremendous increase in physio-mechanical, thermal and dynamic mechanical properties [7]. These results are the proof that fly is very useful reinforced filler material for HDPE and its reduced size, i.e. nano-level is further more useful for future applications [8].

2.2 LDPE Based Composites

These days composites are most commonly used attributes because of its differentiable characteristic which is acquired by the mixing of components. As we spend more time on this planet, this planet or the people are moving towards the direction in which we will be using green technology. Nowadays, fly ash-based polymers are used as filler materials for producing LDPE based fly ash composites. Now if we increase the filler loading in these composites, it will increase its tensile strength as well as it will also increase its modulus of elasticity, but it will also decrease the percentage of elongation [9].

2.3 Epoxy-Based Composites

Epoxy-based composites are low molecular weight pre-polymer or high molecular weight polymers containing at least two epoxide groups. They are mainly used for surface coatings. Liquid epoxy composites have extraordinary ability of mixing and processing with the reinforcement materials in granular form or fibre form [10]. But the overall outcome depends on the combined effort of the materials. Metallic filled composites are mostly deployed in moulds manufacturing, so that small parts of plastics can be manufactured. These mixtures of fibres and aluminium are used for optimizing mechanical and thermal properties of composites for rapid tooling applications [11]. There are various researches done on the epoxy-based composites due to its lightweight and other significant properties in one of these types of studies it is shown that even if we use nano-filler material in smallest ratio possible it will improve the mechanical and thermal property of fly ash-based composites [12]. It was also noted that if we use 5 wt% of fly ash and 2.5 wt% of graphene as filler materials in the manufacturing of composites, then these composites have higher hardness value compared to other fly ash-based composites [13].

2.4 PLA Based Composites

PLA {poly lactic acid} is a matrix material which is used in composites to hold the reinforcing fibres. It is biodegradable in nature; therefore, it is used for making biocomposite materials. In last few decades, PLA based polymer composites are being studied and researched because of the unique properties of these composites such as biocompatibility or biodegradability. Therefore, in one of these researches, electrical and thermal conducting polymer composites were developed on their biodegradable PLA basis [14]. Later, it was found that if we add 1% CNT, then thermal conductivity of ternary PLA composites will increase by at least by 40% compared to binary PLA composites.

In one of the other studies, it was concluded that heat or ionizing radiation-based adhesive composites formulation can offer sufficient strength comparable to shear stress and degree of substrate failure {50–90%} for a variety of adhesive loading in the range of 95 g/m^2 and 300 g/m^2 [14].

2.5 PVA Based Composites

Polyvinyl alcohol is a colourless usually non-toxic thermoplastic adhesive prepared by polymerization of vinyl acetate. Polyvinyl alcohol is a synthetic polymer and is also considered as true biodegradable product as it is superbly hydrophilic and biocompatible. Many researches are being done to review mechanical and water absorption property of PVA bases composites [15]. There are many researches or studies done on PVA mainly to study the effect on mechanical properties of PVA based composites while using fibres as reinforcing materials to manufacture PVA blend films. It was found that one of the serious disadvantages of PVA based composites was its high usage or its high solubility in water. Researches are being done to nullify this disadvantage as well as other disadvantages such as high cost, high water absorption. So that PVA based composites can have a further applications in different fields [16]. Table 1 presents the brief compilation and key findings of fly ash-based polymer composites.

3 Conclusion

Fly ash is a very useful material to be reinforced in various polymer matrix. Optimization of loading and treatment method is very important to get superior results. Proper combination of matrix, fly ash additive and treatment methodology can give promising results and improve the quality of composites. It also helps us in recycling of fly ash because if it is not recycled then it causes health-related problems to humans and other environmental problems [20].

Table 1 Fly ash reinforced different polymer composites

S. no.	Matrix used	Composition	Key result	References
1	HDPE	15–20% fly ash	At 20% by weight flexural strength of the composites is maximum, flexural modulus is also maximum (1260 MPa)	[6]
2	LDPE	20–30% fly ash	At 25% by weight compressive strength improved by 1.44 times and flexural strength improved by 2.16 times	[9]
3	PVA	0.5% crosslinking glyoxal and PVA	It resulted in swelling power decreased from 105.6% to 78.3%	[16]
4	PLA	1.0 wt% of CNT	It was noticed that by adding 1.0% weight of CNT thermal conductivity increased from 10 to 40%	[14]
5	Epoxy	10% fly ash	Stability of blend increased with increase in fly ash content in epoxy	[12]
6	Epoxy	Fly ash volume fraction (10–50%)	It is shown that if the volume fraction is 50%, then the compressive strength is 165.6 MPa which is highest	[6]
7	Epoxy-based composites	NaOH solution 5%, 6% and 10%	It was observed that 10% solution flexural strength of fibre composites was highly improved	[17]
8	PVA based composites	Synthesization of PVA & MXenes	It was observed on their synthesization that thermal conductivity of PVA based polymer composites was highly improved to 47.6 W/(mK), which is higher than some metals	[18]
9	PLA based composites	Helical carbon nanotubes (HCNTs) interacted with PLA matrix	When the procedure was complete, the impact strength value was improved 30%	[19]

- It was noticed that fly ash-based modified epoxy composites with surface treatment have greater impact strength.
- Compressive strength of fly ash composites was found to be improved.
- Flexural strength was also improved.
- It also solves the environmental pollution problem.

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