

EGG SHELL AS A FILLER IN COMPOSITE MATERIALS – A REVIEW

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Abstract: Current focus is on polymer and metal matrix composites for their increased mechanical properties. The strength of the composites is further enhanced by incorporating different types of additives which includes fillers, flame retardants, silanes, coupling agents and so on. One such additives is egg shell powder which influences the strength of composites and thus, gains the attention of researchers for its incorporation in composite fabrication. The work is in progress with respect to utilizing waste egg shell in composite fabrication, which not only finds solution for the waste disposal, but also enhances the strength of composites manufactured. This work is the compilation of work done by different researchers with egg shell in composites, so that the need of its utilization in the manufacture of composites will be stronger.

Keywords: natural fibre composites, chicken egg shell powder, mechanical property, water absorption property

1. INTRODUCTION

Composite materials are made up of one or more reinforcements (discontinuous phase) like fibres embedded in a matrix (continuous phase), resin. The composites are of three types which include metal matrix, ceramic matrix and polymer matrix composite. Polymer composites can be achieved with a wide variety of fibre reinforcements either synthetic in origin e.g. carbon fibre, glass fibres, aramid or natural fibres like flax, hemp, coir, abaca and sometimes hybrids too wherein both synthetic and natural fibres are used together [1]. Synthetic fibres to their credit have, good elasticity can handle heavy loads and are long lasting and are readily available than their natural counterparts. Though synthetic fibres are easy to produce and are available in plenty but come with a disadvantage that they are non-biodegradable and hence are not eco-friendly and leave a trail of carbon footprint right from their production and until disposal [2]. On the contrary, natural fibres are available in plenty either cultivated for the same or available as by-products of agricultural industry and

their properties are comparable to synthetic fibres. Thus, natural fibre polymer composites (NFPC) are possible alternatives to the synthetic fibre composites and are fast replacing synthetic fibres in composite materials [3]. To any type of composites, additives are added, so as to bring about certain positive changes. Among many additives, fillers are the class of additives which when added fill the voids in the composites and because of this makes the end product much stronger. Red mud powder [4], coconut shell powder [5], tamarind extract powders [6] and egg shell powders are the popular natural fillers added.

The most commonly used inorganic filler nowadays in composite fabrication is calcium carbonate being water repellent. The easiest source available for CaCO_3 is chicken egg shell which is produced in plenty every year as a waste material. In US, Environmental Protection Agency (EPA) has placed eggshell waste at 15th place as a waste produced every year and the European Commission regulations treats egg shell as the most hazardous waste [7]. The major source of egg shell waste is poultry, food manufacturing industries, homes,

bakeries and restaurants [8]. The waste management has become a challenging problem as a result of which scientists are giving prime importance for this waste disposal. Egg shells being inexpensive and light weight, finds its application in load bearing materials like automotive industry and other structural applications [9]. Hence, various researchers explored the utilization of this waste chicken egg shell as a reinforcement in variety of composites so that the strength of the composites is improved and also it thus, finds the way for its disposal [10].

2. CHICKEN EGG SHELL AS A FILLER IN COMPOSITE FABRICATION

Chicken egg consists of 60% of white coloured material which is called as albumin, 30% of yellow coloured material which is called as yolk and remaining 10% of the shell which gains the interest of research to be utilized as a filler in any kind of composite material [11]. The structure of an egg shell is shown in Fig. 1 [7]. The weight of the egg ranges from 60 – 60.2 g whereas the weight of the shell will be 6.6 – 7.3 g as discussed in literature [12]. This egg shell constitutes of 95% of calcium carbonate which is the strength giving material, with some number of organic proteins and moisture content. The other elements present in the egg shell are MgO (0.83%), SO₃ (0.66%), P₂O₅ (0.43%), Al₂O₃ (0.15%), K₂O (0.08%), SiO₂ (0.07%), Cl₂O₃ (0.06%) and SrO (0.04%) [13]. The density of the egg shell ranges from 2.50 to 2.65 g/cm³ as reported in the literature [14-16]. Research is carried out by various scientists incorporating egg shell in different types of composite fabrication like metal matrix and polymer matrix composite. The mechanical property of the composites drastically increased with addition of egg shell particles. The major constituent of egg shell being CaCO₃, the water-resistant property of the composites is increased. The investigations until the date, with respect to egg shell and the composites are reflected as follows.

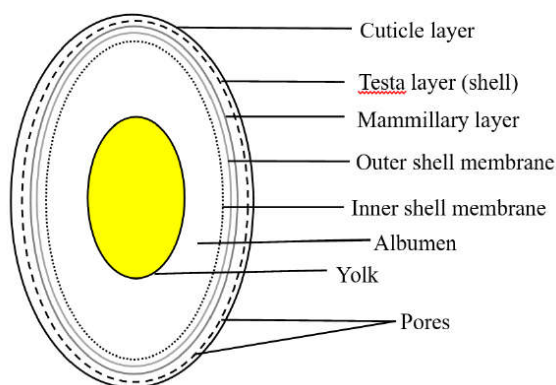


Fig. 1. Structure of an egg shell [7]

3. MECHANICAL PROPERTIES OF THE COMPOSITES WITH EGG SHELL PARTICLES

Egg shells are used as a reinforcement in the composites which has showed improvement in the strength of the composites. It is used as a filler in natural fibre composites, synthetic fibre composites, particulate, laminate and metal matrix composites. Few works have been carried out in this field where different combination of materials were considered to analyse the property of the composites fabricated. Results of the reported work are presented as Table 1. The incorporation of egg shell particles show better interaction with the resin thereby resulting in improved tensile, flexural, hardness, impact, shear strength of the composite materials.

4. WATER ABSORPTION BEHAVIOUR OF EGG SHELL REINFORCED COMPOSITES

Siti S. et al in the year 2009 studied the effect of egg shell particle on LDPE composites. Composites were manufactured by isophthalic acid modified and unmodified egg shell powder composites with different concentration of egg shell powder varying from 5 – 25 %. Water absorption studies was done with respect to ASTM D750-95. It was observed that LDPE showed minimum water absorption, whereas with increasing percentage of egg shell powder, the water absorption rate of the composites increased. This is because of the fact that with increasing percentage of egg shell powder from 5% to 25%, the filler agglomeration is observed which prevents the even distribution of filler and polymer matrix which thus increases the water absorption of the composites [28]. Similar results were obtained by Ali et al in year 2020, who investigated how egg shell brings out the changes with water absorption with respect to egg shell-epoxy particulate composite [19]. ASTM D2842-12 was considered for the analysis. It was observed that with increase in the number of days; the composite exposed to water, the water absorption has increased. The rate of absorption is higher for initial 3-6 days whereas when exposed to 12-18 days, the rate of water absorption is comparatively lesser. After certain duration of time, the optimization is reached which further causes no change or very less change in the water absorption behaviour of the composite. The water absorption also increased with increasing egg shell concentration. The higher percentage of egg shell results in agglomeration resulting failure of the composites.

Tab. 1. Mechanical property of the composites with egg shell powder

Reinforcement	Resin/Composite	Egg shell (ES) (%)	Mechanical properties	Results obtained with respect to egg shell concentration	References
Hemp fibre	Epoxy	7, 14 and 21 (Nano particle)	Tensile test (ASTM D3039) Shear test (ASTM D2344) Flexural test (ASTM D790) Impact test (ASTM D 256)	Tensile strength and shear strength decreased with increasing ES% whereas flexural strength and impact strength increased with increasing ES%	Bhoopathi et al (2020) [17]
Sisal fibre	Epoxy	Calcined and uncalcined (3, 6, 9, 12 and 15)	Flexural test (ASTM D790) Tensile test (ASTMC1557) Impact test Hardness test	Uncalcined ESP composites with 15% ES proportion gave good mechanical properties to the composite	Oladele et al (2020) [18]
-	Epoxy	10, 20 and 30%	Tensile test Flexural test Impact test (ASTM 6957) Hardness test (ASTM 5091)	Maximum hardness and tensile strength were observed for 20% egg shell reinforced composite, Maximum flexural strength and impact strength -30% ESP	Ali et al (2020) [19]
-	Epoxy	4, 8, 12 and 16	Hardness test (ASTM D-2240) Tensile test (ASTM D 638) Flexural test (ASTM D790) Impact test	Strength of the composites increased with increasing ES %. Maximum result was obtained for composites with 16 % ES.	Ruaa et al (2019) [20]
-	Epoxy	10, 20	Flexural test (ASTM D2344-84) Vickers hardness test	Composites with 20% ESP exhibited maximum hardness and flexural strength	Shashir et al (2017) [21]
Glass fibre	Polyester	5, 10	Flexural test (ASTM D7264) Vickers hardness test (ASTM E384)	5%- greater flexural strength Same hardness for both 5% and 10% egg shell composites	Pavan H (2016) [22]
-	Sugar sap 100/1000 epoxy	Egg shell nano powder (1-10 wt %)	Flexural test Modulus Toughness	Maximum for composite with 4 wt % of ES nano powder	Tiimob et al (2015) [23]
Al-Cu-Mg	Particulate composite	Carbonized and uncarbonized 2-12	Tensile test Flexural test Impact test	Carbonized 12 % ES gives better mechanical property	Hassan et al (2015) [24]
Calcium carbonate	Polyester	15, 20	Tensile test (ASTM D 638) Flexural test (ASTM D 790) Water absorption	20%-high tensile strength 15%-high flexural strength 20%- greater water absorption	Senthil J (2015) [25]
Al	Metal matrix composite	2-12% Egg shell powder	Tensile test Hardness test	Properties increased with increasing ESP %	Agunsoye et al (2015) [26]
Calcium carbonate	Polyethylene from sugarcane	5, 10, 20, 30 and 40	Tensile test Flexural test Impact test	The strength of the composite, decreased with increasing ES %	Boronat et al (2014) [13]
Soy-protein isolate	-	Egg shell nano powder (3, 5 and 10 wt%)	Tensile test Young's modulus	Increased up to 15% after which the strength reduced	Rahman et al (2014) [27]

Bhoopathi et al in year 2020 studied the effect of variation of egg shell powder in the untreated and alkali treated hemp fibre reinforced epoxy composites [17]. With increasing egg shell powder concentration, the water absorption of the composites reduced which proves that egg shell can be used as a filler in composite fabrication. Rahim et al in year 2019, studied the effect of egg shell in epoxy composite according to ASTM D-570. It was observed that egg shell powder was used in increasing concentration of 4, 8, 12 and 16%. With increasing concentration of egg shell powder, the water resistant property of the composites increased [20]. Similar results were shown by Shashir et al in year 2017, where the greater percentage of egg shell powder in epoxy composite decreased the water absorption behaviour of the composites [21].

5. CONCLUSION

Composites are the materials which gives superior property because of the combination of two different materials. In the field of composites, egg shell particles are of prime importance, because it increases mechanical strength of the composites manufactured and also gives the way for waste management. Through the literature, it is quite evident that the egg shell particles incorporated in any composites like metal matrix or polymer matrix; enhances the tensile strength, flexural strength, shear strength, impact strength and hardness at different concentrations of egg shell in combination of metal/fibres/resin at different fractions. The water absorption behaviour of the composites decreased drastically in case of natural fibre reinforced polymer composites after incorporation of egg shell particles. The work done in literature with respect to egg shell as a filler in natural fibre reinforced polymer composite is less. The tribological studies with respect to egg shell as fillers is still to be explored. Hence, after this review study, it is evident that; there is scope for utilization of egg shell particle as a filler in composites and to study their wear behaviour so that it can be used for any structural applications, automobile and marine applications in future.

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Conflict of interest

Authors declare there is no conflict of interest.

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