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ANALYSIS OF SUSTAINABLE POLYESTER TILES OF DOMESTIC WASTE

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ABSTRACT
Sustainable unsaturated polyester resin composite tiles were prepared using snail shell powder by open mould technique. The snail shell powder filler was obtained from snail shell, a domestic waste. The filler characterized for pH (7.61), bulk density (1.33), specific gravity (1.80 g/cm^3), refractive index (1.45), oil absorption (5.0 g/100 g), and moisture content (14.01%) was incorporated into the polymer matrix at 0 to 30 wt. % filler content. The tensile, and compressive strength of the tile samples decreased with filler content whereas the impact, hardness, and specific gravity increased with filler content, and were generally greater than those of cured unsaturated polyester resin at any filler content considered. The tile samples containing 15, and 25 wt. % snail shell powder were vitreous while the samples containing 10, 20, and 30 wt.% snail shell powder were semi – vitreous. The low water absorption property of the tile samples makes them suitable for household utilizations in areas such as kitchen walls, floors, backlashes, and shower walls, and should justify the use of low - cost snail shell powder in the composite industry. This will lead to a cost - effective handling and management of snail shell waste thereby, providing a clean environment.
Keywords: Unsaturated polyester resin, snail shell powder, tile, tensile strength, water absorption, domestic waste, open mould.

INTRODUCTION
Unsaturated polyester resin (UPR) composite title, industrially known as polymer concrete is a novel material system that involves cost - effective processing technique. They are introduced in the building sector because of their improved properties which have been of concern in several industrial applications. These tiles consist essentially of load bearing fine aggregates (fillers) embedded in weaker polymer matrices. The aggregate which provides reinforcement in the material system may be particles, platelets, or fibers, and are generally added to improve the material systems stiffness, strength, and rigidity. The polymer matrix, a resin acts as binder of aggregates and macroaggregates and helps to maintain the position and orientation of the embedded aggregates [1]. The resin undergoes polymerization after the addition of additives such as catalyst and accelerator to produce hardened composite (tile) product.

Unsaturated polyester resins have wide range of structural applications because of their special properties which include low cost, easy processibility, and handling. Similarly, UPRs exhibit good corrosion resistance, mechanical property, and desirable light weight. These factors are also, responsible for their applications in different industries which include automotive, coating, and electrical [2 - 4].

There is a growing interest in the search for sustainable materials to replace traditional fillers in the production of unsaturated polyester resin composite tile (polymer concrete). Thus, artificial microfillers ($CaCO_3$) and waste aggregate (basalt and limestone) [5], waste glass [6], sand [1,7,8], huracrepitan pod particles [9], and granite [10 - 12] have been utilized to produce composite tiles. Similarly, eggshell [13], and marble particles [14 ,15] have been investigated for utilization in polyester composite (tile) production.

The present study reports the sustainable utilization of snail shell powder in formulating unsaturated polyester resin composite tiles. The snail shell powder prepared from snail shell collected from Ihiagwa market in Owerri West Local Government Area, Imo State, Nigeria and sieved to 75µm particle size was used within filler content, 0 to 30 wt.% in the formulation of unsaturated polyester resin composite tiles. The prepared title samples were characterized in terms of tensile, compression and impart strength, hardness, specific gravity, and water absorption.

Snail shell is a domestic waste and could be seen littering our homes, villages, and market places. Snail shell has no known domestic and industrial applications and can be a source of environmental pollution due to the activities of microbes and bacteria in the shells. Thus, an appropriate combination of snail shell powder and polymer matrix is a sustainable, cost - effective way of developing a light weight, innovative, and advanced material system capable of protecting the earth thereby, ensuring clean and green environment. Snail shell particle also, has high refractory temperature thereby, making it a suitable reinforcement material to produce heat resistant metal - matrix composites [16].

EXPERIMENTAL

The unsaturated polyester resin (UPR) used in this study was obtained from Campal Scientific and Technology Co. Ltd, Onitsha, Nigeria. It is a product of Daily Polymer Corp, Kaohsiung City, Taiwan. The snail shell was collected from Ihiagwa Market, Owerri West Local Government Area, Imo State, Nigeria. It was sieved to 75 µm particle size. The chemicals methyl ethyl ketone peroxide (MEKP) (initiator) and cobalt naphthenate(accelerator) were purchased from local stores at Onitsha, Nigeria. Silicon oil was used as a mould release agent.

Characterization of snail shell powder

The snail shell powder was characterized using standard methods: pH (ASTM D 1208 – 960), specific gravity (ASTM D 153 - 84), refractive index (ASTM D 1208 - 98), oil absorption (ASTM D 281 – 12), chemical composition (ASTM D 5381 - 94), bulk density, and moisture content (ASTM D 1510, 1983).

Preparation of UPR tile samples

Required amounts of unsaturated polyester resin (UPR) and snail shell powder (SSP) were used to prepare composite tiles at snail shell powder content, 0 – 30 wt.%. Methyl ethyl ketone peroxide was used as the initiator at the amount 2% based on the weight of resin while cobalt naphthanate functioned as the accelerator. The prepared tile samples were poured into aluminum moulds (17x17cm) prepared by rubbing silicon oil on their inner surfaces and kept for drying for 12 h after which they were demoulded and stored in tight lid container for subsequent use. A cured unsaturated polyester resin containing no snail shell powder was prepared to serve as reference (control).

Analysis of prepared tile samples

The title samples were analyzed for tensile, impact, and compression strength, specific gravity, and hardness using standard methods. The water absorption property was determined as described previously [18].

RESULTS AND DISCUSSION

Physical properties of snail shell powder

The properties of snail shell powder used in formulating unsaturated polyester resin composite tiles are shown in Table1.

Table1. Physical properties of snail shell powder

Parameter	Value
Bulk density	1.33
Moisture content (%)	14.01
Specific gravity (g/cm^3)	1.80
pH of slurry	7.61
Refractive index	1.45
Oil absorption (g/100 g)	5.0

The determined pH of aqueous slurry of snail shell powder (7.61) showed that snail shell powder was slightly basic. The bulk density of snail shell powder was determined to be 1.33. Bulk density, also known as apparent density or volumetric density is the mass of many particles of a material divided by the total volume they occupy. The snail shell powder had a moisture content of 14.01%.

Chemical composition of snail shell powder

Energy dispersive x - ray spectrometer analysis of snail shell powder showed the abundance of calcium oxide (CaO) (94.76%) in the powder, followed by small proportion of aluminium oxide (Al_2O_3) (2.13%). The other oxides are present in minute quantities. The presence of Al_2O_3 in snail shell powder might have contributed to increase in the hardness of the formulated tile samples.

Properties of prepared tile sample

The properties of the prepared tile samples are illustrated in Figures1 to 6.

Tensile strength

Figure 1 showed the effect of snail shell powder content on the tensile strength of formulated tile samples. From the figure, it is evident that the tensile strength of the unsaturated polyester resin tile samples decreased with snail shell powder content and are lower than the tensile strength of cured unsaturated polyester resin (43.70 MPa). This may be due to insufficient adhesion between the snail shell powder particles and the resin matrix resulting in reduction of surface contact area between the filler particles and resin matrix. This cumulatively decreased the tensile strength of the formulated tile samples which were in the range, 27.33 to 39.27 MPa. In one of our reports [10], the tensile strength of granite dust formulated tile samples were found to decrease with filler content. Similarly, Achukwu *et al*. [6] who studied waste glass reinforced unsaturated polyester resin composites reported decreases in composite strength with filler particles.

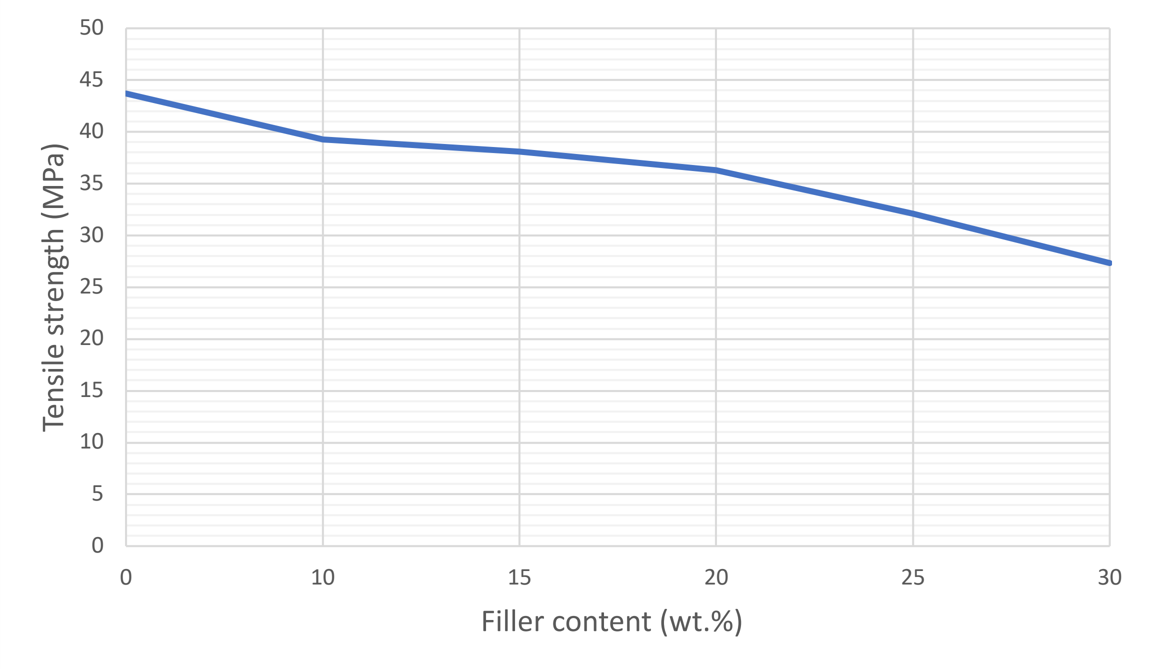

Fig. 1 Effect of filler content on tensile strength on prepared tile samples.

Compression strength

Compression strength is the ability of a material to withstand axially directed pushing forces [1]. Figure 2 illustrates the effects of addition of snail shell powder filler on the compression strength of the tile samples. Like was obtained for sample tensile strength, the compression strength of the formulated tile samples decreased with filler content and were generally lower than that of cured unsaturated polyester resin (90.10 MPa).

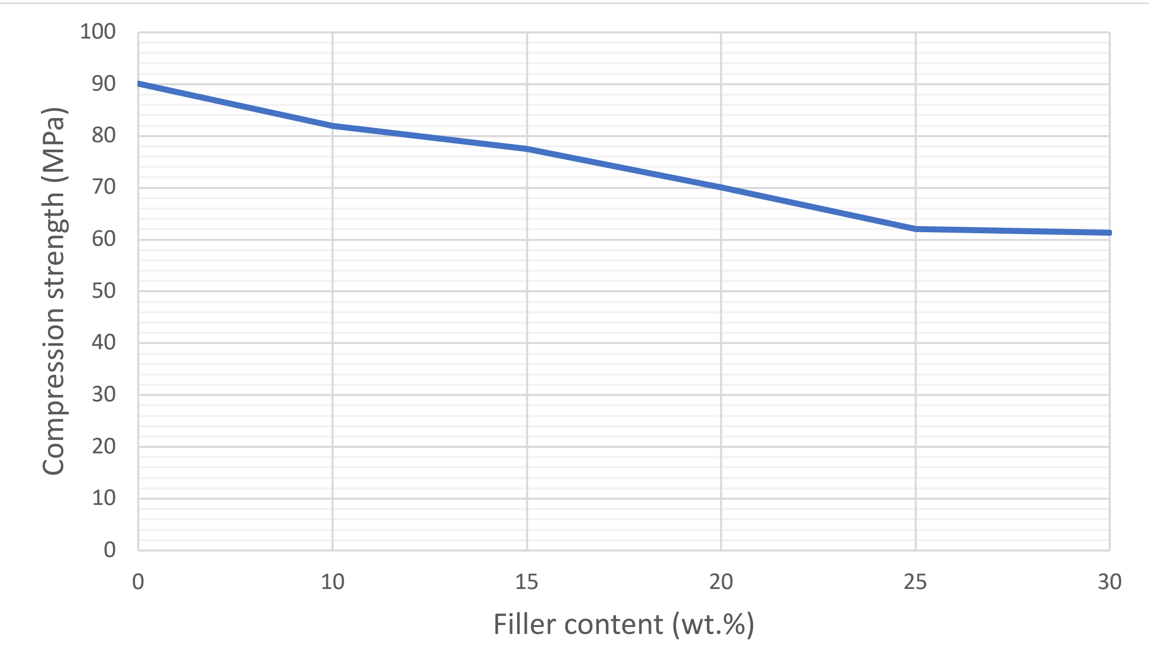

Fig. 2 Effect of filler content on compression strength of prepared tile samples

Sultana *et al*. [1] attributed lower compression strength of formulated sand tile samples to lower magnitude of cross - linking reactions. The highest compression strength (81.91 MPa) was obtained for 10 wt.% SNP formulated tile sample while the least (61.33 MPa) was for 30 wt.% SNP formulated tile sample.

Impact strength

The effect of snail shell powder content on the impact strength of formulated tile samples is shown in Fig. 3. The figure showed increasing impact strength of the samples with filler content and were in all cases higher than that of cured unsaturated polyester resin (0.27J). Ibeneme et al. [9] reported increases in impact strength of unsaturated polyester resin tiles formulated with huracrepitan pod with filler content. Conversely, Chukwu *et al*. [17] in their studies reported that the impact strength of snail shell filler reinforced terephthalic unsaturated polyester resin decreased with filler content. The impact strength of the formulated tile samples in this study were in the range, 0.27 to 1.53 J.

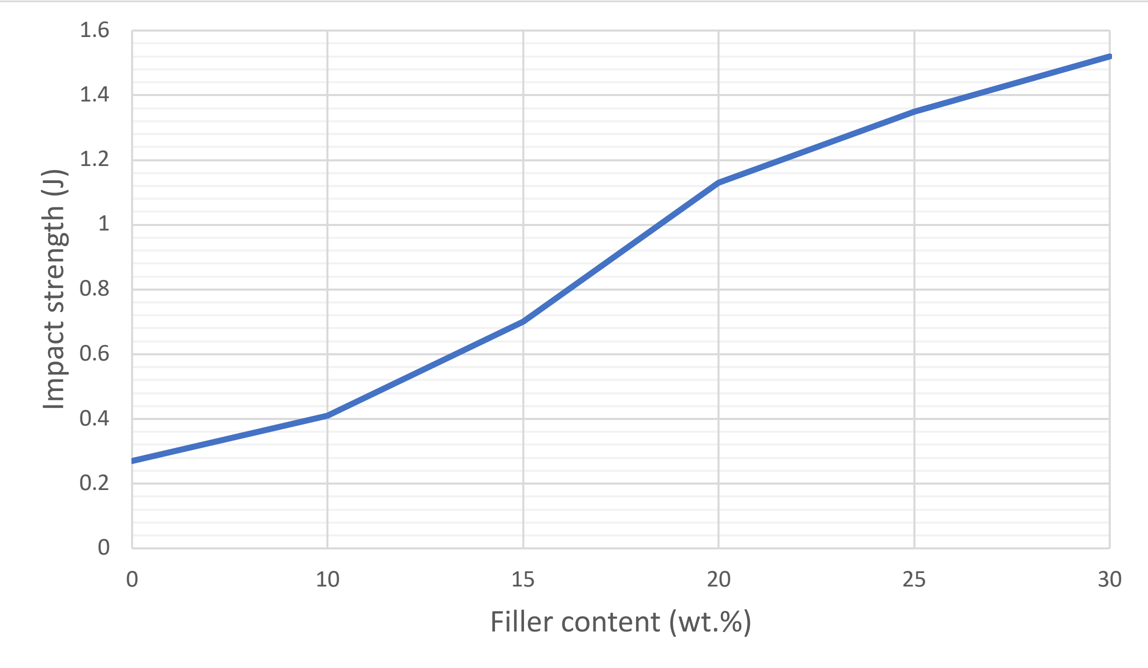

Fig. 3 Effect of filler content on impact strength of prepared tile samples

Hardness

The hardness of the formulated tile samples illustrated in Fig. 4 showed that the sample hardness increased with filler content and were higher than that of cured polyester resin (7.83 Hv). The observed increase in sample hardness with filler content is attributed to the reduction of resin brittleness due to strong matrix - filler interaction. While Umunnakwe [16] reported no definite order of variation of reinforced unsaturated polyester resin composites hardness with filler content, Chukwu *et al*. [17] found that snail shell filled terephthalate unsaturated polyester resin hardness generally decreased with filler content. Material hardness is a property that depends on strength, toughness, ductility, elasticity, and stiffness. The presence of Al_2O_3 in snail shell powder may in part also, explain the increases in hardness of the tile samples studied.

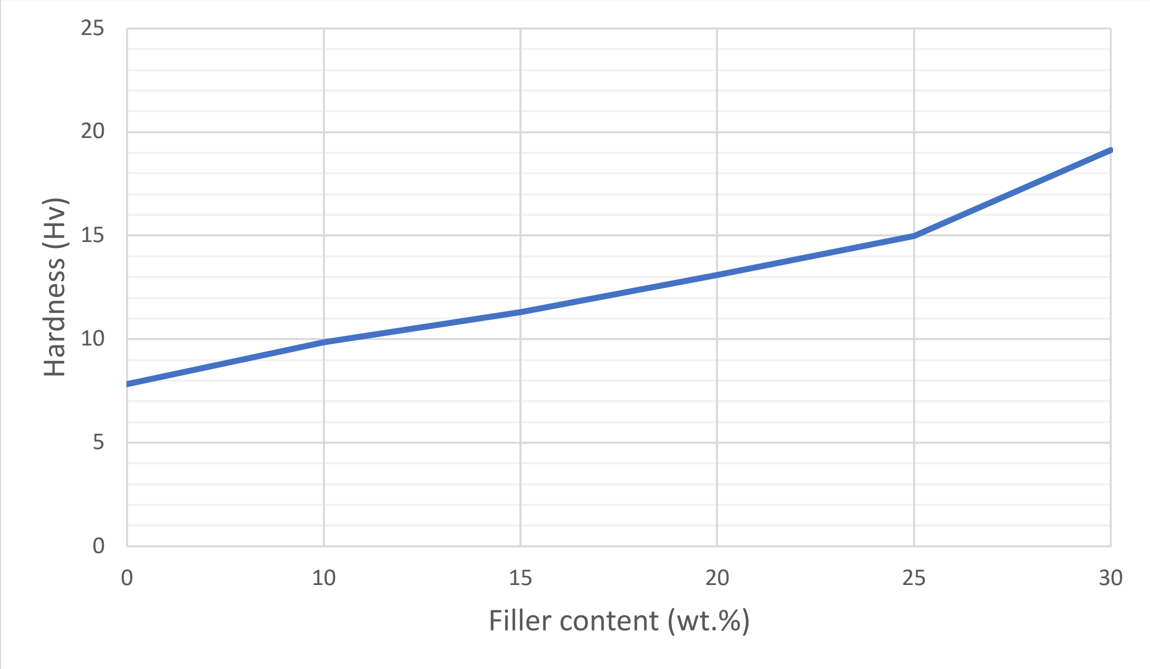

Fig. 4 Effect of filler content on hardness of prepared tile samples

Specific gravity

The specific gravity of the prepared tile samples is illustrated in Fig. 5. The specific gravity of cured unsaturated polyester resin is 1.09. The specific gravity of snail shell powder formulated tile samples were generally higher than that of cured unsaturated polyester resin, attaining maximum value [1.29] at filler content 15 wt.%, and lowest value [1.16] at filler content, 20 wt.%

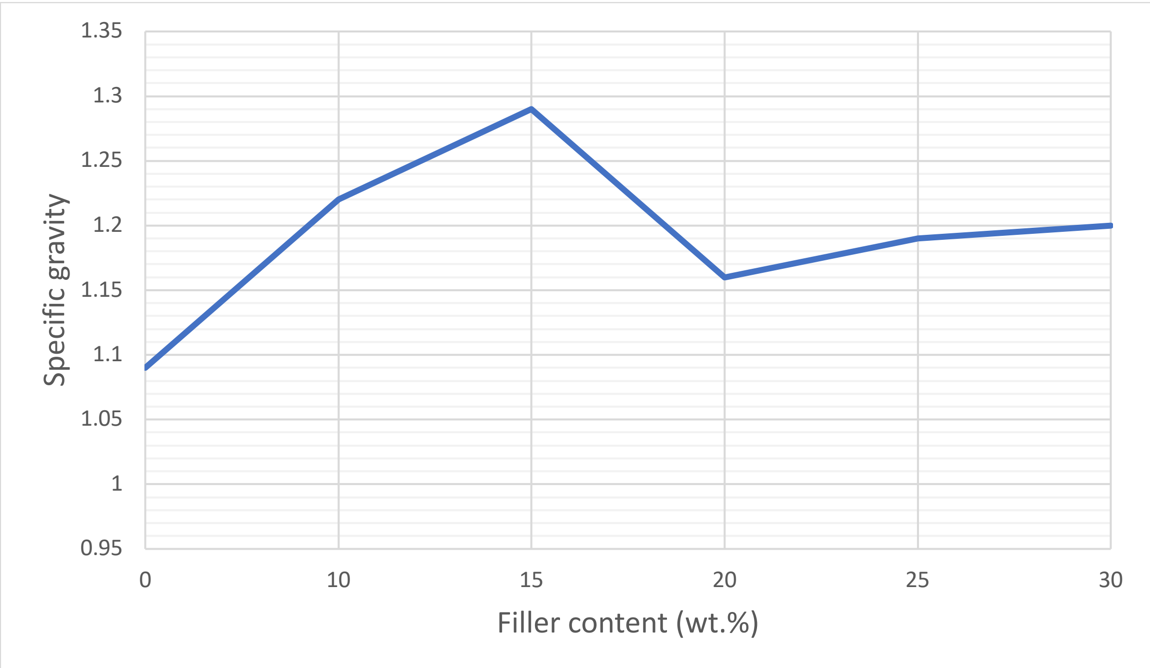

Fig. 5 Effect of filler content on specific gravity of prepared tile samples.

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Water absorption

The water absorbed by the prepared tile samples as a function of filler content is illustrated in Fig. 6. The water absorbed by snail shell powder prepared tile samples decreased with filler content within 15 - 30 wt.% filler incorporation. The decrease of water absorption with filler content is attributed to the resulted increased tightness, which decreased the pores in the composite tiles available for water absorption. The water absorbed by cured unsaturated polyester resin is 4.39%. Snail shell powder prepared tile samples absorbed the least amount prepaid by tile samples absorbed the least amount of water (2.27%) at 25.0 wt.% filler content, The water absorbed by snail shell powder prepared tile samples at filler contents,15 and 25 wt.% was more than 0.5% but less than 3%, and consequently, the tiles are classified as vitreous [ANSI A137.1] [19]. They are suitable for indoor applications in areas such as shower walls, and floors. On the other hand, the water absorbed by tile samples at filler contents 10, 20, and 30 wt.% are semi - vitreous [19] and suitable for applications in areas that wet occasionally such as kitchen backsplashes. Sultana *et al*. [1] who characterized sand reinforced polyester composites reported general decrease of water absorbed by composites with filler content. The water absorption property of sand reinforced polyester composites was also, reported to decrease with increase of polyester resin to sand ratio and was attributed to the decrease in pores because of increasing adhesion and cross - linking with the increase of polyester ratio to sand as well as ɤ-irradiation dose [8].

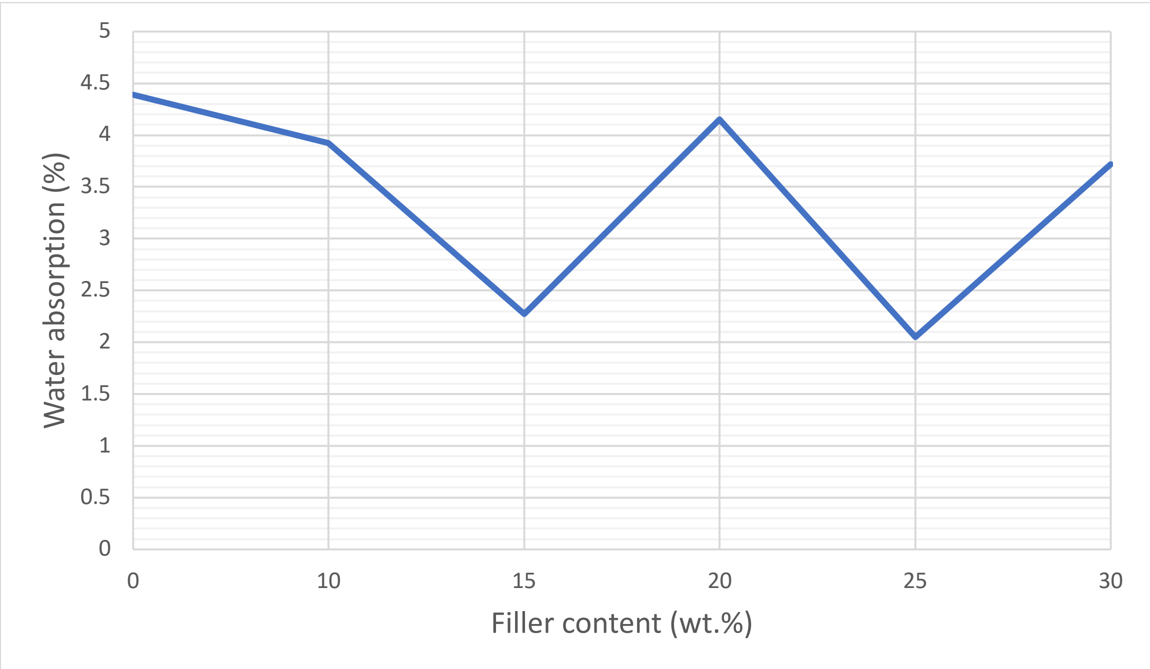

Fig. 6 Effect of filler content on water absorption of prepared tiles samples

Water absorption is a very important property of tile materials that can dictate environment of use. Tiles that resist water absorption generally have diverse areas of application. Thus, a tile that absorbs a lot water is not suitable for outside environment use but can be utilized as wall tile.

CONCLUSION

(i) Snail shell powder was used successfully to prepare unsaturated polyester resin composite tiles suitable for household applications. The snail shell powder possessed the following determined properties: pH (7.61), bulk density (1.33), oil absorption (5.0 g/10 g), refractive index (1.45), specific gravity (1.80), and moisture content (14.01%)

(ii) The tensile, and compressive strength of the composite tiles decreased with filler content and were lower than that of cured unsaturated polyester resin.

(iii) The impact strength, hardness, and specific gravity of the tile samples were greater than that of cured unsaturated polyester resin.

(iv) Tile samples containing 15, and 25 wt.% snail shell powder absorbed more than 0.5% water but less than 3% water and are vitreous. On the other hand, tile samples containing 10, 20, and 30 wt.% snail shell powder absorbed more than 3% water but less than 7% water and are semi - vitreous.

(v) The water absorption properties of the formulated tile samples indicate their potentials for household applications in such areas as shower walls, floors, and kitchen backsplashes.

(vi) The present study has highlighted the technical feasibility of producing sustainable lightweight unsaturated polyester resin composite tiles possessing low water absorption property using snail shell powder. Successful industrial utilization of snail shell powder in the composite industry will entail proper handling and management of snail shell waste resulting to clean environment.

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