PREPARATION AND PROPERTIES OF POLYPROPYLENE AND PA 6 COMPOSITES REINFORCED WITH ARMENIAN TUFF STONE

Prof. Karnik Tarverdi, PhD
Wolfson Centre for Materials Processing Brunel University London, United Kingdom
Zaruhi Madoyan, MA
National University of Architecture and Construction of Armenia

Abstract

The present paper discusses preparation, testing and possible uses of new composites, which consists of commodity and engineering polymers such as polypropylene (PP) and polyamide (PA6) reinforced with waste Armenian tuff stone powder.
The paper will discuss extrusion and blending of the materials using co-rotating twin screw extruder with the inclusion of compatibiliser for enhancing the properties of the composite. The microstructure, thermal and mechanical properties of the composites have been examined following injection moulding of tensile test samples with a view of using these composites for added value applications.

Keywords: Tuff stone, polymers, extrusion blending, characterization

Introduction

A **Polypropylene (PP), Polyamide(PA6)**

Polymer composites consist of either a thermoset or thermoplastic polymer, with the inclusions of inorganic fillers such as a calcium carbonate and glass fibres, which together build up the structure of the composite. The physical properties are strongly dependent on the chemical structure and ratio of individual groups in the plastic as well as the fillers employed. These have a very large influence on the overall spectrum of properties oh the polymer composite which includes the additives for the final composite formulation. Polymer composites are extensively used in the manufacture of lightweight, flame retardant and abrasion resistant components for the automotive, aeronautical industries and household goods. Composite materials made of various plastics and additives include: textile-reinforced plastic hoses, glass and natural fibre reinforced sheeting, metal reinforced profiles for windows, carpet, cable, tyres, composite bumpers and many more[1].

Properties of polymers.

1. Density. Typically 800-1500 kg/m^3 for uniform polymers.
2. Insulation. Thermal insulation: conductivity of solid polymers is about 0.2 W/m K, i.e four orders of magnitude lower than copper.
3. Expansion coefficient ≈ range 60-200x10^{-6}/K.
4. Dimensional stability. A few polymers can absorb some liquids, causing swelling or even dissolution, accompanied by changes in physical properties.
5. Chemical resistance. Can be very good but depends on the chemical nature of the polymers.
6. Burning. All polymers can be destroyed by live flames or excessive heat, although the Rate of destruction depends on the type of polymer.
7. Processing. It is normal to make in one piece three-dimensional articles with

repeatable precision [12].

Tuff stone

For petrographical purposes, tuff is generally classified according to the nature of the volcanic rock of which it consists; this may be the same as the accompanying lavas if any were emitted during an eruption, and if there is a change in the kind of lava which is poured out, the tuffs also indicate this equally clearly. Rhyolite tuffs contain pumiceous, glassy fragments and small scoriae with quartz, alkali feldspar, biotite, etc. Iceland, Lipari, Hungary, the Basin and Range of the American southwest, and New Zealand are among the areas where such tuffs are prominent. The broken pumice is clear and isotropic, and very small particles commonly have crescentic, sickle-shaped, or biconcave outlines, showing that they are produced by the shattering of a vesicular glass, sometimes described as ash-structure. The tiny glass fragments derived from broken pumice are called shards; the glass shards readily deform and flow when the deposits are sufficiently hot, as shown in the accompanying image of welded tuff [7].

Pyroclastic rocks consisting chiefly of angular blocks blown out while solid are classed as volcanic breccias; those with an abundant matrix of ash-size fragments are called tuff-breccias. The composition of these coarse deposits is extremely varied, but most consist of accessory ejecta of intermediate and siliceous composition, and a few contain large proportions of accidental, non-volcanic debris. No matter how breccias and tuff-breccias originate, they accumulate rapidly and hence are seldom sorted or stratified [10].

All examined tuff beds show a uniform assemblage of juvenile magmatic components. These comprise completely recrystallized platy and cuspate relict glass shards up to 200 µm in diameter, pumice fragments are rarely preserved but may reach 500 µm in length [8].

In Armenia there is an abundant of a variety of tuff stones and some of the existing tuff stones which in essence are volcanic rocks with rich geological background and there is evidence that the rocks have had significant interaction with ice.

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These rocks have been found in New Mexico, Vesuvius-Italy, Minoan tuff-Thira, Greece etc. [9].

Few of the Armenian tuff types are:

1. Ani
2. Artick
3. Yerevan
4. Byurakan
5. Felzic

Ani type tuff, when compared with other tuff stones has the highest strength. These types of tuffstones have yellow-orange colour and maybe the tuff has got its texture at high temperatures. It contains SiO_2-67-70%, Al_2O_3-15-25%, Fe_2O_3-2.4-2.76%:

Density-1169-1740 kg/m^3, compression strength 37 MPa, porosity 28-50%, water absorption 11-32%:

Artick type tuff, colours are pink-violet, but the colours can range from white to black. It contains SiO_2-64-66% and its colours are the reason of titan and iron oxides.

Density-750-1550 kg/m^3, compression strength 8.6-16 MPa, porosity 32.4-67.6%, water absorption 33%:

Yerevan type tuff stone, colours are red in the high spheres of the stone, red-pink colours can change to black. It contains SiO_2-60.91-65.04%, Al_2O_3-13.18-18,17%, Fe_2O_3-2.26-6.47%:

Density-1100-2200 kg/m^3, compression strength 3-55 MPa, porosity 10-55%, water absorption 3-40%:

Byurakan type of tuff stone colours are pink-red with black lines. They contain SiO_2-62,65%, Al_2O_3-15,92%, Fe_2O_3-5,26%:

Density-1600-2200 kg/m^3, compression strength 15-55 MPa, porosity 10-40%, water absorption 3-13%:

Felzic type of tuff stone colours are older than others, so their colours can be very different, from yellow, brown, dark pink. It contains SiO_2-59-73%, Al_2O_3-12-18%, Fe_2O_3-3-5%, MgO-0.3-1.2%, CaO-2-4%, Na_2O+K_2O-5-10%:

Density-1460-2350 kg/m^3, compression strength 2-80 MPa, porosity 8,6-39,8%, water absorption 2.9-24,0%[6].

Experimental

The Ani tuff stone was chosen for these preliminary extrusion compounding experiments because Ani tuff stone has high strength and is abundant in Armenia as waste stone after trimming and cutting sections for the buildings industry.

The tuff stone was powdered using a pulverizer followed by sieving to particle sizes below 100micron after which the powder was pre blended separately with different concentrations of powdered PP and PA6 and compatibiliser. The powdered blends were fed into a co-rotating intermeshing twin screw extruder using a volumetric feeder.

The extruder temperatures were set first for PP following which the temperatures of the extruder was raised for processing PA6. (Table 1).

The extrudates were stranded and cooled via a water bath and pelletized before drying ready for injection moulding into tensile test bars.

Table 1. Composite samples prepared for evaluation

Sample 1	PP- 100%
Sample 2	PP- 50%, Tuff-50%
Sample 3	PP- 40%, Tuff-60%
Sample 4	PP- 50%, Tuff-50%, Kraton-50% (FG1901 GT)
Sample 5	PA 6- 100%
Sample 6	PA 6- 50%, Tuff-50%
Sample 7	PA 6- 40%, Tuff-60%
Sample 8	PA 6- 50%, Tuff-50%, Kraton-50%

All 8 samples were extrusion blended and pelletized using in house Polylab extruder and pelletizer. The temperature range used for both polymers was between 200-250˚C, duration of extrusion compounding and pelletizing of each sample was about 30 minutes.

Results and discussions

Following sample preparations the test specimens were subjected to Flexural tests using an Instron tensile testing rig and for the impact tests a Charpy testing instrument was used.

The results of the flexural and impact tests are presented below.

Figure 1. Flexural modulus test results

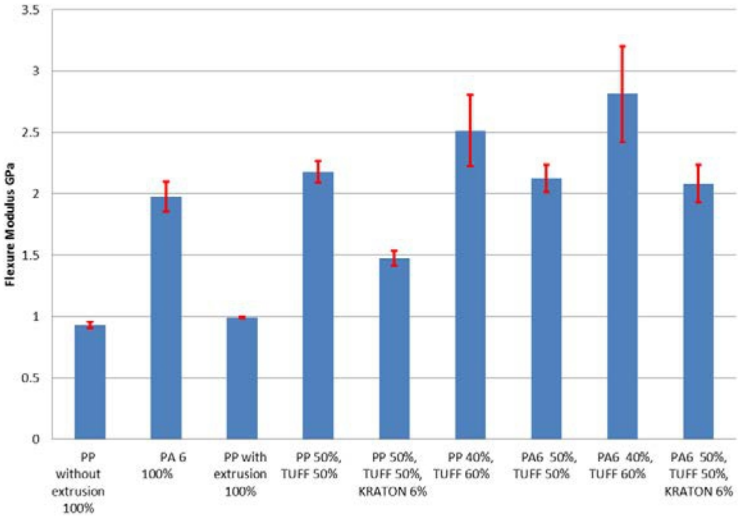


Figure 2 Flexural strength measurements

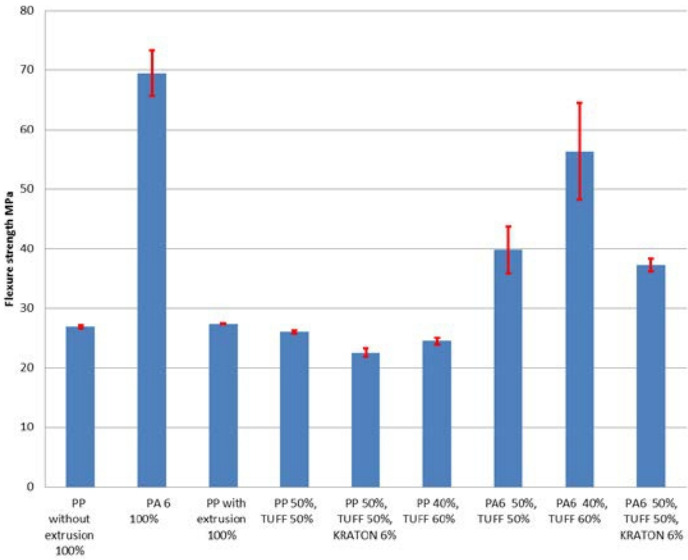
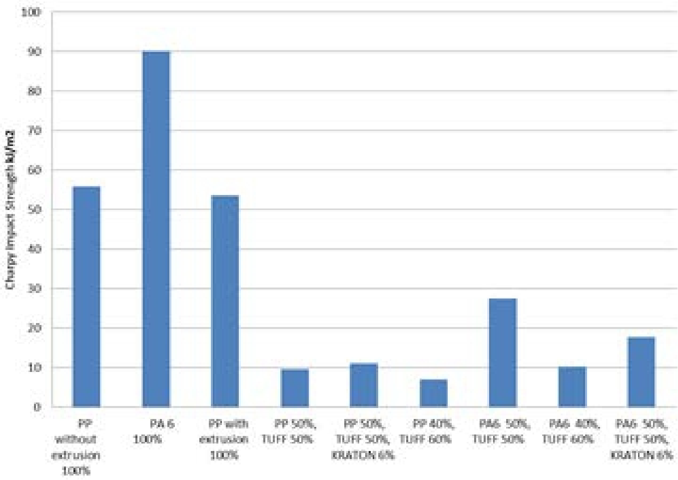


Figure 3 Impact strength measurements



Conclusion

Using specialised twin screw extrusion technology with the appropriate screw profile and length to diameter ratio extruder optimum blending of fillers with base polymers can be achieved.

In this work careful sieving and tuff stone powder selection has also helped to optimise blending and incorporating the tuff powder with the base polymers with the inclusion of a compatibiliser to try and further enhance the flexural properties of the composites.

The results indicate that the addition of tuff stone powder particularly with regard to the flexural strength and modulus of the specimens can enhance mechanical properties of the polymers when optimised polymer and filler blending and dispersion is achieved. In the present paper, high strength, stiffness, and toughness values have been reported for the Polypropylene and Polyamide containing fairly high loadings of the tuff filler. It has been demonstrated that the use of selected and processed tuff stone of this type has the potential to add value to polymers by relatively increasing mechanical performance at minimal additional cost or even reducing the final costs by using recycled tuff stone powder.

These experiments have also demonstrated that despite tuff stone being soft and porous, with the appropriate treatment the composite can be made hydrophobic even under extreme of temperature and humidity conditions.

Further work

This preliminary work has demonstrated that waste tuff stone powder can be used as a substitute for other fillers like calcium carbonate in polymers, but further work needs to be carried out to evaluate the properties of different tuff stones when blended with different polymers and used in the long term.

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