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Lightweight expanded aggregates from the mixture of waste automotive plastics and clay

Peiyao Liu, Rifat Farzana, Ravindra Rajarao *, Veena Sahajwalla

Centre for Sustainable Materials Research and Technology (SMaRT@UNSW), School of Materials Science and Engineering, UNSW Australia, Sydney, NSW 2052, Australia

HIGHLIGHTS

- Light weight aggregates were manufactured from waste automotive plastics and clay.
- 39.5% higher porosity and 28.5% lower bulk density was achieved compared to clay.
- This innovative and eco-friendly approach could help reduce auto plastics in landfills.

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ABSTRACT

Significant amount of waste associated with end of life vehicles enter waste stream each year and are usually disposed of in landfill, creating an environmental burden. Recycling automotive waste is very tedious and difficult due to its heterogeneous composition and nature. It is critically required to develop a solution to recycle and reuse these potential resources. In this paper, a novel recycling approach is established to produce lightweight aggregate by incorporating automotive shredded residual (ASR) plastics into clay at 1200 °C. The physical properties of lightweight aggregate such as bulk density, porosity and water absorption have been investigated. ASR plastics as pore-forming or gas releasing agent increased the porosity of the clay mixture. Incorporation of 2 wt% of ASR plastics into clay composite lead to a benefit of approximately 30% bulk density decrease and 40% porosity increase compared to the reference clay material used in this study. The obtained superior lightweight and porous aggregate products by using ASR plastics can be used in thermal insulation materials and also as substrates in soilless cultivation. This innovative approach could also help reduce the volume of autoplastics in landfills and could be a potential replacement of conventional additives in manufacturing composite materials for building applications.

1. Introduction

Lightweight aggregates is a type of coarse aggregate that are commonly used in manufacturing of building products such as concrete block, lightweight concrete structures, and as insulator material for road constructions [1,2]. Light weight aggregates are highly porous and spherical ceramic products with lower density not exceeding 1200 kg/cm^3 [3]. The light weight aggregates are also used in other applications such as water treatment, hydroponic substrates, and aquaponics etc. depending upon their physical and chemical properties [4,5]. The use of lightweight aggregates in concrete has following advantages: (a) due to the lower density of aggregates, dead load can be reduced which result in lower footing sizes (b) reduction in column sizes and beam dimensions which results in larger space availability (c) porous and sintered core in aggregates results higher thermal insulation (d) enhanced fire resistance due to existence of pores and (e) spherical shaped aggregates improves concrete properties [1,3,6]. Raw materials for lightweight aggregates can be natural or artificial origin. Natural materials mostly used for manufacturing are igneous (pumice and tuffs), sedimentary (clay stone or shale) or very low grade metamorphic rocks [7,8]. Lightweight aggregates have also been manufactured by using various industrial by-product waste as raw materials such as granite waste [3], fly ash [1], reservoir sediment [8], municipal solid waste incinerator fly ash [9], waste glass [10], industrial sludge [11], electrical insulator waste [12], biomass [13]. Lightweight aggregates are manufactured by quick heating at high temperatures which has ability to bloat. To obtain good quality lightweight aggregate, the following conditions are necessary: (a) material should contain substances which produced gases at high temperature (b) material should produce viscous liquid which

* Corresponding author.
E-mail address: r.rajarao@unsw.edu.au (R. Rajarao).

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can trap gases and (c) during material cooling, it should produce external glassy film [14]. The gas production is very crucial step as it is the main reason for expansion and lightweight property of materials. So gas production can be natural (thermally unstable minerals or materials) or by substances added to raw materials. Coal, waxes and hydrocarbons are widely used as artificial gas producing materials in industrial lightweight aggregate manufacturing process [15]. In recent years, concrete industry is facing major challenges due to declining availability of raw materials and also to use renewable resources or waste materials in manufacturing process to achieve sustainability. To overcome difficulties, more attention should be given to study the feasibility of using different waste materials in lightweight aggregate manufacturing.

Plastics are widely used materials due to their exceptional lightweight and durable properties and also inexpensive, hence usage of plastic has increased over last 60 years. Worldwide plastic production is estimated to be around 311 million tonnes in 2014 including thermoplastic, thermoset plastics, adhesives and coatings [16]. More than 50% of produced plastics are used in packing and agricultural films which are single use. 25 to 30% of plastics are used in manufacturing consumer durable goods such as electronics and vehicles. The long infrastructure applications such as pipes, structural materials utilize the rest 20–25% plastics [17]. Most of the plastics are not biodegradable and hence produced plastics may persist for centuries resulting waste management issues and environmental damage. In recent years, the significant increase in use of plastic to replace traditional metals in automotive construction is witnessed. Plastics in automotive vehicles are increased from around 10 kg in 1960s to 180–200 kg in year 2000 s [18]. Today, average car constitutes between 15–25% plastic and will increase tremendously in near future due to increase by consumers for fuel efficient cars [19]. Around 50 million tonnes of automotive waste is generated each year around the globe [20]. Due to development of technology and increase of automobiles, dumping and management of end of life vehicles have become significant environmental and health issues. Around 75 wt% of the waste automotive car which constitutes metals and other valuable materials such as lubricants, tyres etc. are recovered and recycled. The 25% of remaining automotive waste which contains plastics, foam, wood etc. are shredded and commonly named as 'automotive shredded residue' (ASR), which are generally disposed in landfills [21]. Mostly, the discarded automotive waste comprises of plastics, rubber, textiles, wood and smaller percentage of metals. The combination of various materials in automotive waste makes recycling very tedious and difficult. With a significant increase in usage of plastics in automotive sector and also increase in vehicle production demands a necessity for sustainable approach to manage automotive plastics waste and also a recycling solution to reduce environmental damage. In our group, we have made an extensive effort to use waste automotive glasses as silicon source to synthesise ferrosilicon alloy [22,23]. Recently, we also used electronic wastes as resources to produce various valuable products such as nano silicon carbide, carbon micro fibers, activated carbon, precious metals etc [24–27]. In the literature, only few studies have attempted to recycle automotive plastics through thermal pyrolysis process.

In this work, we report the use of automotive plastics and clay to produce lightweight expanded clay aggregates. The approach is to utilize waste automotive plastics as gas releasing materials to transform clay to light weight expanded aggregates. Lightweight aggregates were produced by adding various ratios (1–5%) of automotive waste plastics in clay mixture. Sintering of clay/auto plastics pellets was performed at industrial working temperature 1200 °C for 20 min in horizontal tube furnace. The physical and chemical properties of raw materials and lightweight clay aggregate were investigated. Incorporation of 2 wt% of ASR plastics in aggregate results in a benefit of approximately 39.5% porosity increase and 28.5% bulk density decrease compared to the reference clay material. Such porous aggregate can be used to control thermal and acoustical insulation in concrete or as substrates in soilless cultivation. This innovative approach offers a novel solution for increasing recycling rate of automotive waste and could be a new opportunity for manufacturing lightweight aggregates as an input for building materials applications.

2. Materials and methods

The details of waste automotive plastics and clay, methods used to characterize, sintering procedure and testing of produced lightweight expanded clay aggregates are described in this section.

2.1. Materials

The clay used in this study was provided by Brickworks Limited, Sydney. The supplied clay materials were uneven in size and hence screened with 2 mm sieve to filter out the big size grains. The shredded automotive waste which is composed mainly of plastics was obtained from OneSteel Recycling Company located at Newcastle, Australia. The obtained automotive plastics waste was also sieved 1 mm to 2 mm size for the experiment. Images of shredded automotive waste plastics and clay are shown in Fig. 1.

2.2. Characterisation of materials

X-ray florescence (XRF) spectroscopy and ICP ultimate analysis were performed on received clay and automotive plastic waste to determine the elemental content. The respective data are shown in Table **1**.

Thermal stability and decomposition temperature of both clay and automotive plastics waste was determined by using STA 6000 PerkinElmer thermo-gravimetric analyser (TGA) from 30 °C to 1200 °C at the heating rate of 20 °C/min.

X-ray diffraction analysis was performed on clay sample to determine the material composition and crystalline structure.

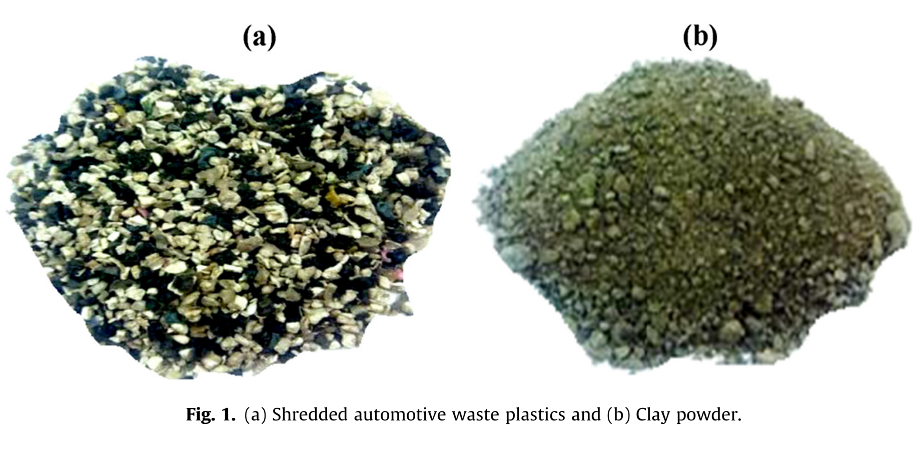

Fig. 1. (a) Shredded automotive waste plastics and (b) Clay powder.