Structural Material from Waste Plastic

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Received 8 October 2002; accepted 17 June 2003

ABSTRACT: In efforts to contribute to community development, particularly in the context of Egyptian communities, waste plastics materials were successfully recycled without the difficult task of separation and reused to economically produce new structural material. Recycling was performed by mixing molten waste plastics with sand to produce these new materials. Samples with different percentages of plastics and different particle sizes of sand were used in the process. Materials showed acceptable density and high compressive strength, which was shown to be at a maximum with contents of about 30–40% waste plastic. Furthermore, certain types of sand having different colors were used to produce attractive materials, suitable for decorative uses. © 2003 Wiley Periodicals, Inc. J Appl Polym Sci 91: 2543–2547, 2004

Key words: waste plastic; recycling; structural materials; density; compression

INTRODUCTION

Worldwide, efforts continue to be made to maintain a clean environment, free of pollutants that are generated mainly from either industrial or agricultural wastes. As part of these ongoing actions recycling has been in common usage in developed countries since the late 1960s. The introduction of convenience products to consumers in the 1950s, however, also led to what some have termed a "throwaway society."

According to environmental conservation laws, the recycling of wastes constitute operations that permit extracting materials or reusing them, such as fuel or extracting metals and organic materials to treat the soil or refining the oils. Recycling and composting are encouraged by environmental action plans. The informal private sector, represented by rubbish collectors, has been involved in waste recovery and recycling for many years because of the high value of recyclable materials.

Today plastics are an integral part of everyone's lifestyle with application varying from commonplace articles to sophisticated scientific and medical instruments. Designers and engineers readily turn to plastics because they offer combinations of properties not available in any other materials. However, there is a downside: plastic is one of the least friendly materials. Low-cost plastics such as single-use packaging appear more frequently in the waste stream than the polymers used in making durable goods. Some of the plastic products other than packaging enter the waste stream one year or more after production. The rapid growth of waste from electrical and electronic equipment can be attributed to the speed of new developments in technology, which has resulted in a reduction in product life to less than 2 years in some cases, for both domestic and commercial products. In 1998 the amount of waste electrical and electronic equipment, for example, in Europe reached an estimated 6 million tons, an amount expected to double over the next decade.[1]

The global figure of dismantled cars was around 24 million in 1995, generating 2.2 million tons of plastics scrap.[2]

Plastic is a nonbiodegradable material, so we cannot eliminate plastic wastes either by land filling or burning. Use of landfills to dispose of plastic wastes prevents plant roots from growing and negatively affects agricultural enterprises. In addition plastic waste generates considerable volume; although the weight of plastics in the waste stream is only 8% it takes up nearly 20% of the volume in landfills. Burning of plastic wastes produces great amounts of harmful gases, which affects all kinds of organisms.

Currently there is increasing worldwide interest in biodegradable polymers and composites, which are viewed as a major part of global efforts to overcome serious environmental problems in the 21st century. Biodegradable polymers offer scientists a possible solution to waste-disposal problems associated with traditional petroleum-derived plastics.[3–15] For scientists the real challenge lies in finding applications that would consume sufficiently large quantities of these materials to allow cost reductions, thus allowing biodegradable polymers to compete economically in the market.

Contract grant sponsor: International Bureau, Germany.

Journal of Applied Polymer Science, Vol. 91, 2543–2547 (2004)

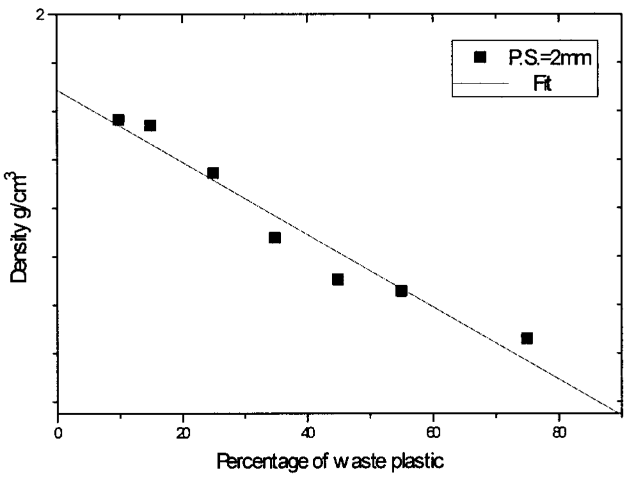

Figure 1 Density as a function of waste plastic percentage for samples with a sand particle size of 0.85 mm.

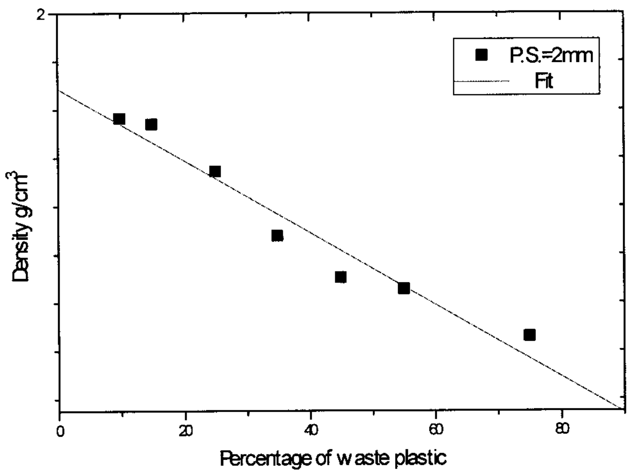

Figure 2 Density as a function of waste plastic percentage for samples with a sand particle size of 2 mm.

The superior performance of today's traditional plastics is the outcome of continued R&D efforts over the last several years; however, existing biodegradable polymers were introduced to public use only a few years ago. In terms of application, biodegradable polymers are classified into three groups: medical, ecological, and dual application; whereas in terms of origin they are divided into two groups: natural and synthetic.[16] The cost of biodegradable polymers can be reduced by mass-scale production, which is feasible only through constant R&D efforts of scientists to improve the performance of biodegradable plastics. Manufacture of biodegradable composites from such biodegradable plastics will enhance the demand for such materials.

Recently critical discussion about the preservation of natural resources and recycling has led to renewed interest in renewable raw materials.[17] There is now interest in the use of biopolymers for applications in which synthetic polymers have traditionally been the materials of choice.[18]

Attention focused on polymer recycling has increased in the past decade because more efficient reuse of materials will reduce the quantities sent to landfills, as well as reduce raw material extraction.[19] Recycling of waste plastics has been an interesting subject in the field of environmental science and technology for a long time and several methods have been proposed for recycling waste plastics.[20–29] Recycling of plastics mainly includes three recycling options: (1) mechanical recycling, (2) chemical recycling by depolymerization, and (3) energy recovery (e.g., use of calorific value of polymer wastes[30]).

In the present study trials were carried out to contribute toward the development of the community, in the context of development in Egypt, by recycling waste plastics and reusing them in the production of an economically new structural material.

EXPERIMENTAL

Materials

Materials used in this work were classified as sand and waste plastic. Sand was used with different particle sizes ranging from about 0.2 to 3.75 mm. The preparation of the required particle sizes was performed by screening apparatus. In this study the waste plastics used were mainly polyethylene films and containers, representing the majority of the waste plastic. The percentage of waste plastic ranged from 5 to 95.

Equipment

The equipment used in these study included screening apparatus (Sieve shaker), mixer, burner, and mold.

Procedure

The preparation of the samples proceeded as follows. The sand was screened by using the sieve shaker for

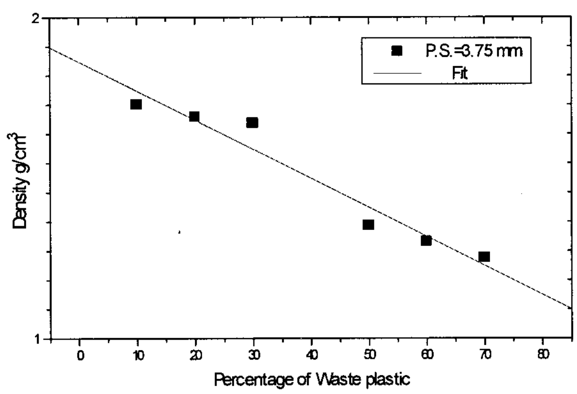

Figure 3 Density as a function of waste plastic percentage for samples with a sand particle size of 3.75 mm.

TABLE I
Effect of Waste Plastic Percentage on the Density of the Samples

Particle size (mm)	Waste plastic (%)	Density (g/cm^3)
0.2	10	1.9
	20	1.75
	30	1.7
	40	1.6
	50	1.51
0.65	10	1.9
	20	1.71
	30	1.63
	40	1.5
	50	1.39
1.3	20	1.88
	30	1.8
	40	1.7
	50	1.3

about 20 min. The required percentage of waste plastic was weighed and melted by using a burner for about 1 min, allowing the waste plastic to self-burn. The required amount of sand was prepared and added to the molten plastic. The mixture was thoroughly mixed manually for about 15 min to ensure homogeneity. After that the mixture was discharged into a cubic (7 cm^3) mold. Finally, the mold was allowed to cool in open air for about 30 min and subjected to the measurements after the sample was removed from the mold.

Measurements

Two tests were performed for the samples in this study: density and compressive strength.

RESULTS AND DISCUSSION

Density

Figures 1–3 show the density versus the percentage of waste plastic for different particle sizes of sand. These

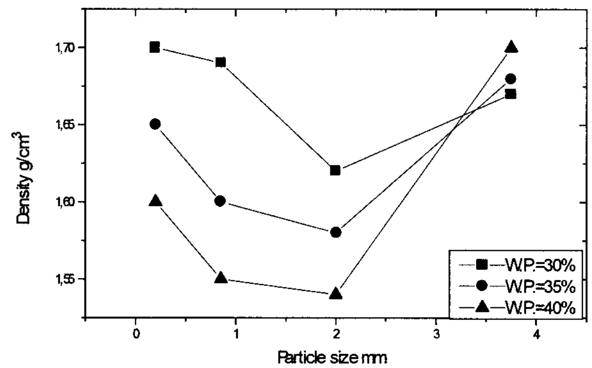

Figure 5 Linear plot of density versus particle size for samples with different waste plastic percentages.

figures represent samples with small (0.85 mm in Fig. 1), medium (2 mm in Fig. 2), and large (3.75 mm in Fig. 3) particle sizes of sand. Other sizes are listed in Table I. As seen in these figures and Table I the density of the samples decreases with increasing the percentage content of plastics because the density of the plastic (~ 0.9 g/cm^3) is lower than that of sand (~ 2.3 g/cm^3). As a result by increasing the amount of plastic at the expense of the amount of sand in the sample, the density of the sample decreases. Experimental data were linearly fitted as shown in Figures 1–3. The relation between density and the waste plastic percentage was nearly the same for all particle sizes of sand, as indicated by the empirical equation from line fitting to be $\rho = 1.87 - 0.007X$, where X is the percentage of waste plastic.

In Figures 4–6 the density is plotted against the particle size of the sand in samples of different percentages of waste plastic. Again, the density decreases as the particle size of the sand increases because larger particles create very small voids in the product; therefore the volume increases but the density decreases. Fine particles of sand lead to greater compactness of the samples, resulting in higher density. This is made

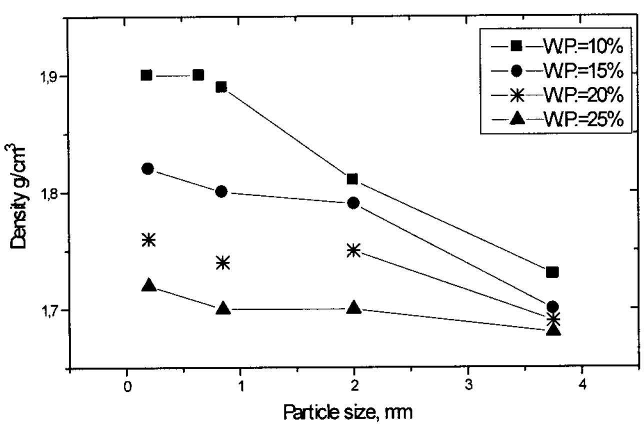

Figure 4 Linear plot of density versus particle size for samples with low waste plastic percentage.

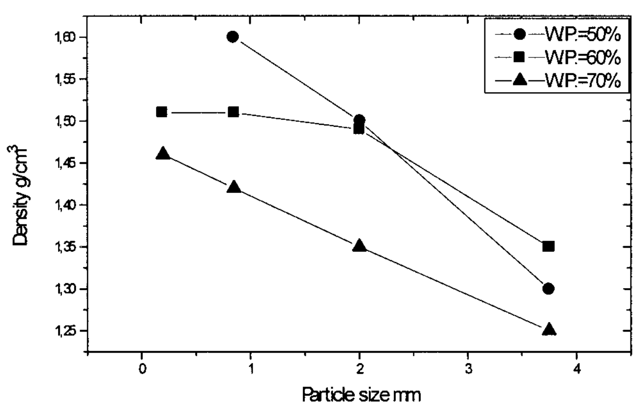

Figure 6 Linear plot of density versus particle size for samples with a high waste plastic percentage.

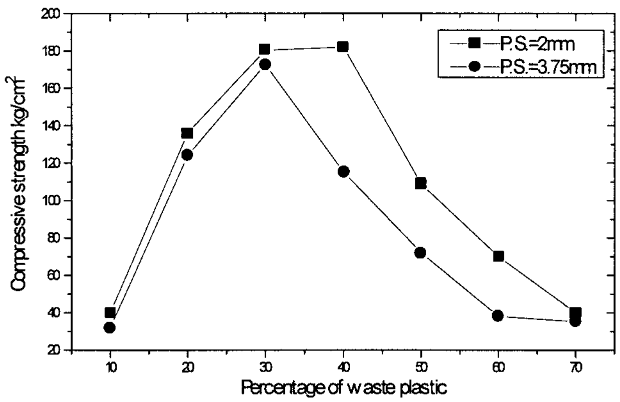

Figure 7 Linear dependency of compressive strength on the waste plastic percentage for samples with a small sand particle size.

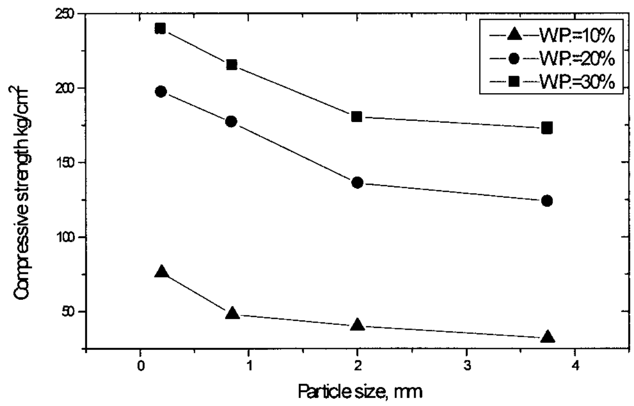

Figure 9 Effect of the particle size on compressive strength for samples with a low waste plastic percentage.

clear in Figures 4–6, given that the density appears to be nearly constant at small particle sizes then decreases sharply at large particle sizes of sand for the cases of low (10–25%) and high (50–70%) waste plastic percentages. However, it starts to increase again at larger particle size in samples with 30–40% waste plastic content, although the explanation for this is lacking.

Compressive strength

Figures 7 and 8 present the dependency of compressive strength on the percentage of waste plastic. These figures show that the increase of percentage of plastic leads to a greater increase in the compressive strength, to a certain limit, followed by a somewhat sharp decrease, after which it became fairly constant. This phenomenon may be explained as follows. The amount of plastic increases the binding force of the network of plastic and sand particles, such that all the sand particles are surrounded by plastic, which consolidate to form the network. As the amount of waste plastic increases, at the expense of the amount of sand, the compressive strength increases because there are fewer bonds between sand and plastic compared to bonds of the plastic itself. As a result, the compressive strength decreases because the compressive strength of the sand–plastic bond is greater than that of the plastic–plastic bond. Finally, at a higher percentage of waste plastic the effect of the sand–plastic bond is negligible, and the compressive strength is nearly independent of the percentage of waste plastics, as seen clearly in the case of sand particle size of 0.85 mm (Fig. 7), for available values of experimental data. The maximum compressive strength values vary according to the particle size of sand, in the range of 30–40% waste plastic.

Figures 9 and 10 show the effect of particle size on compressive strength, where it may be observed that the increase in particle size of sand decreases the compressive strength. Likely this phenomenon is attributable to the greater distribution of large particles over that of fine particles of sand through the mixture.

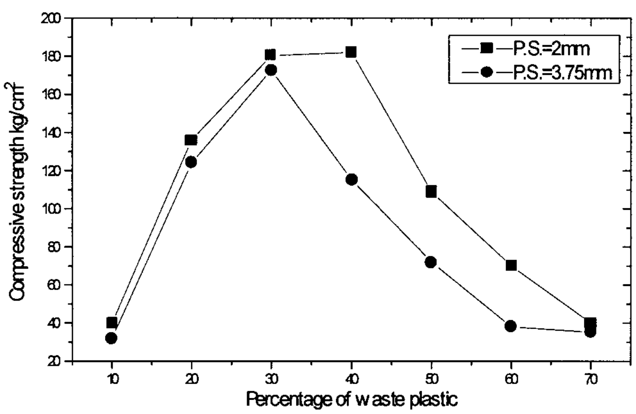

Figure 8 Linear dependency of compressive strength on the waste plastic percentage for samples with a large sand particle size.

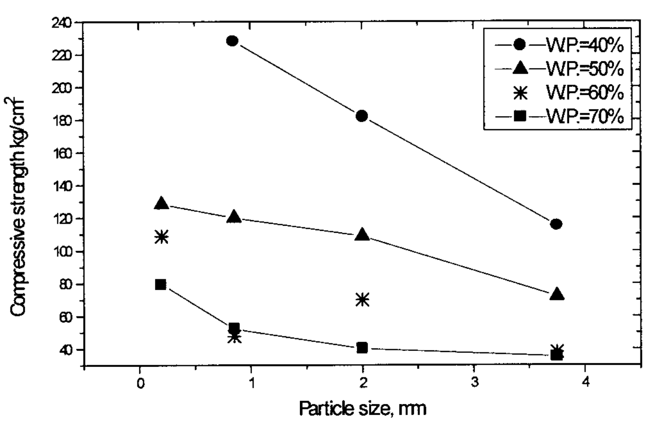

Figure 10 Effect of the particle size on compressive strength for samples with a high waste plastic percentage.

Moreover, the creation of very small voids of large particles decreases the compressive strength compared to that of the network-compacted samples having smaller particles of sand. As a result, the compressive strength decreases as the particle size of sand increases. The effect of compactness is obvious in these figures because the dependency of the compressive strength on the particle size of sand at large size is less than that at small size. Higher waste plastic percentages (Fig. 10) show a negligible effect of particle size on the compressive strength, as shown in the cases of 50, 60, and 70% of waste plastic contents, because the effect of the sand–plastic bond is smaller or negligible compared to the effect for samples of low waste plastic percentages (Fig. 9).

CONCLUSIONS

In this work trials were successfully carried out in production of structural material from waste plastics, which represents a major contribution to communities everywhere, although the experiments were performed in the context of Egyptian communities. Structural measurements of density and compressive strength were performed. The results showed that density decreases concomitantly with increases in both particle size and percentage of waste plastics. The compressive strength increases up to certain limits of waste plastic percentage, after which it decreases; and it decreases as the particle size of sand increases. The maximum compressive strength obtained was in the range of 30–40% waste plastic.

Support for this research was provided by the International Bureau in Germany. Helpful discussions with Dr. H. Abu El-Anien and measurements performed by Mr. Hisham (Civil Engineering Department) are gratefully acknowledged.

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